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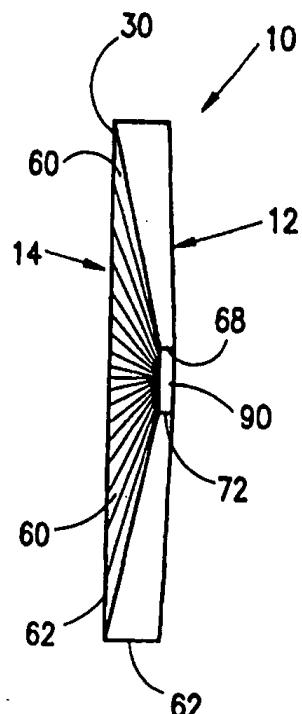
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(71) Applicant: INWAVE, INC. [US/US]; 29 West Milwaukee Street, Jainsville, WI 53545 (US).	Published <i>With international search report.</i>
(72) Inventor: ONUFRYK, Michael; 9 Wickford Way, Fairport, NY 14450 (US).	<i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>
(74) Agent: SHAW, Brian, B.; Cumpston & Shaw, Suite 850, Two State Street, Rochester, NY 14614 (US).	

(54) Title: MULTI PRISM IMAGE ENHANCING LENS SYSTEM AND METHOD OF MAKING SAME

(57) Abstract

A prismatic lens (10) having a plurality of integral prisms (60), wherein the prisms (60) surround a central non prism area (90) in an apex portion (72) in-base (62) out orientation. Each prism (60) is adjacent or contacting two other prisms (60) to encompass the non prism area (90). The present invention may include a conical, spherical or aspheric lens member (30). Further, the plurality of prisms (60) may be disposed on an object side (12) or an image side (14) of the lens (10), so that a corrective prescription curvature may be formed on the lens member (30) on either the object (12) or image (14) side of the lens (10).



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MULTI PRISM IMAGE ENHANCING LENS SYSTEM AND
METHOD OF MAKING SAME

Technical Field:

The present invention generally relates to an image enhancing system employing a plurality of integral prismatic elements disposed on a lens member, and more particularly, to a prismatic lens having a plurality of integral prisms circumscribing a central non prism area, the prisms disposed in an apex in, base out orientation about the non prism area.

10 Background Art:

U.S. Patent No. Re: 28,921 discloses an automatic visual sensitivity and blind spot measuring apparatus for projecting a spot at different locations on a screen to be viewed by the person being tested along with means for the person to indicate perception of the spot for subsequent evaluation.

U.S. Patent No. 1,990,107 relates to a reflectoscope used in the examination of an eye. The reflectoscope includes mirrors for reflecting an image so that the eye can be observed in the correct orientation to prescribe lenses for correcting refractive dysfunctions.

U.S. Patent No. 4,264,152 relates to an apparatus for moving an image of a target in certain preselected ways to stimulate predetermined types of eye movements.

U.S. Patent No. 4,298,253 relates to an apparatus for presenting test images to a viewer at different distances without modifying the visual angle or acuity of the images.

U.S. Patent No. 3,423,151 relates to auxiliary prismatic lenses mountable on an eye glass frame for use by persons having cataracts. The lenses extend the field of view of the person beyond that provided by ordinary lenses by focusing images beyond the range of the normal lenses onto the pupil of the eye.

U.S. Patent No. 2,442,849 relates to a method for producing a pair of lenses for providing balanced binocular vision.

U.S. Patent No. 4,772,113 relates to eyeglasses for improving the vision of people with macular degeneration, optic

5 nerve damage or similar low vision problems, in which their central vision has deteriorated. The eye glasses include two lens assemblies, each having a magnifying lens with two convex surfaces and a reducing lens with two concave surfaces. The reducing lens incorporates a prism ring which shifts and focuses a
10 highly intensified light image onto an undamaged peripheral portion of the retina. A disadvantage of these eye glasses is that the highly magnified and intensified light image would be focused on the bad or damaged peripheral portion of the retina. Another disadvantage of these glasses is that the lens do not have a central
15 clear or non prism area for accommodating the person's good central vision. Also, in those instances where the highly magnified and intensified light image would strike the central functional area of the retina damage and/or overlapping would occur, resulting in a blind area or diplopia (double vision).

20 U.S. Patent No. 4,673,263 relates to eyeglasses for enhancing the vision of people with macular degeneration, optic nerve damage, or similar low vision problems in which their central vision has deteriorated. The eyeglasses comprise of a single element prismatic lens with bifocal which unlike U.S. Patent
25 No. 4,772,113 which projects a strong magnified beam of light to the macula.

U.S. Patent No. 5,155,508 relates to eyeglasses for enhancing the vision of people that have retinitis pigmentosa or glaucoma with constricted fields. The eyeglasses include three
30 functional prisms and a non prism area spaced about a central portion. Two of the three prisms are oriented base out on the horizontal axis, the third prism is located on the lower vertical axis,

base out, the non prism area is opposed to the third prism across the central portion.

U.S. Patent No. 3,628,854 relates to a fresnel prism for special applications, such as diagnostic testing. The fresnel prisms are mounted to normal prescription corrected glasses by capillary action. The capillary mounting is subject to air bubbling during temperature and humidity changes. The fresnel prisms have relatively poor light transmission and the multiple images transmitted or projected to the eye are blurred due to the many concentric prismlets that are pressed into the soft plastic. The fresnel prisms have a number of other disadvantages such as: projection of people in crowds when people move in all directions, this causes diplopia especially when the right eye looks to the right and the left eye is looking through the nasal edge of the left spectacle lens, this is also true when the eyes are looking to the left.

These multiple prismlets reduce light transmission, which reduces vision and causes night blindness and mobility problems. The multiple concentric prismlets cause many reflections of the same object, especially light bulbs, and hence, "one thousand points of light", which causes chromatic dispersion. Due to the number of multiple concentric prismlets, contrast is greatly reduced and patients are constantly looking through a fine grid. With fresnel prisms the patient must rotate their eye to look into the prism to see the expanded field.

U.S. Patents No. 4,779,977 and 4,288,149 and *The Optician*, Volume 163, No. 4237, page 18, dated 1972 all relate to the concept of mounting or cementing small prismatic buttons or prisms to a patient's normal prescription corrected glasses. An exemplary reference of such small prisms are disclosed by Dr. Norman Weiss in the referenced *The Optician*. The primary disadvantages or difficulties associated with the use of such

buttons and/or prisms is prism blur which is difficult to tolerate, creating confusion between frontal and peripheral images particularly in crowds where people are moving in all directions causing diplopia for the wearer.

5 An eye disease known as neovascular senile macular degeneration (N.S.M.D.) in which the central vision, (macula) is greatly impaired, often results in blindness by virtue of blood vessels growing and bursting in the macula of the eye.

10 A known eye glass modification intended to expand the central field of view for people having retinitis pigmentosa, glaucoma, hemianopia involves the amorphic telescope lens system, in which one or more telescopes are mounted on each eye glass. These telescopes minify the images so that more information can be seen at one time in the same field.

15 Disadvantages of this form of field expansion is that multiple images are seen by each eye with the images approximately half size so that detail is lost. Also, the telescope(s) extend outwardly a significant distance from the eye glasses and are cosmetically very unappealing. These eye glasses with telescopes mounted are 20 several times heavier than normal glasses making them uncomfortable to wear and constantly slipping from the wearer's ears and nose due to the generated torque.

Another known vision expanding lens in the prior art, involves the use of a see-through reflector or mirror, functioning as 25 a beam splitter, mounted on the eye glass frame extending from the nose at a predetermined angle. The disadvantages of this type of vision expanding lens are that the eye glass wearer sees two separate images, front and rear which can be quite confusing. The mounting of the reflector or mirror to the eye glass frame is 30 complicated, and results in the reflector or mirror mounted in an exposed position where it can be readily damaged and/or disoriented from the predetermined position.

Still another attempt to expand the field of persons with poor vision involves special high-powered magnifying glasses capable of magnifying an object up to six times, while allowing vision from the peripheral area to enter the eye. Disadvantages of 5 this approach are that these glasses resemble goggles and protrude nearly three inches from the eye and nose. They must be worn with soft contact lenses, they are heavy and cumbersome, and cosmetically unappealing.

Therefore, a need exists for an image enhancing lens 10 having a greater transmission of available light by reducing at least one of reflection, refraction and absorption of light by the lens. The need also exists for lenses for eyeglasses to enhance the field of view of persons suffering from retinitis pigmentosa, glaucoma with constricted fields, hemianopia, macular degeneration, myopia, 15 nystagmus without the person suffering the problems and disadvantages of the prior known efforts to expand a person's field of view. A further need exists for inexpensive, light weight, single element prescription corrected eyeglasses with bifocal(s) that are cosmetically appealing. The need also exists for an image 20 enhancing lens that can be readily employed in a variety of optical systems, wherein the energy transmission through the lens is enhanced without introducing significant aberrations.

Disclosure of the Invention:

The present invention includes a prismatic lens having a 25 plurality of integral prisms on a lens member, wherein the prisms surround a non prism area in an apex in, base out orientation. Each prism is adjacent or contacting two other prisms to encompass the non prism area. The present invention may incorporate a number of alternative design parameters including formation on a conical, 30 spherical or aspheric lens member. Further, the plurality of prisms may be disposed on an object side or an image side of the lens.

The images thus passing through the lens are one to one, without minification, magnification or relocation. The prisms are understood to be prismatic elements functioning as a prism, though an integral portion of the lens.

5 In one embodiment, the prismatic lens member is employed in an ophthalmic prismatic corrected, image enhancing, vision enhancing lens, an ophthalmic lens, and includes 360 prisms with all apexes terminating toward the central non prism area of the lens. In the first embodiment, one of the object side and image 10 side of the lens member is substantially defined by a generally spherical base curve.

The ophthalmic lens is a single element lightweight prismatic image enhancing lens, wherein the interface between adjacent prisms is substantially invisible to the naked eye. The 15 lens may include a prescription curvature and bifocals as required to provide lenses for persons having at least one eye having a central visually sensitive functional area of the retina for receiving the normal central visual field of view and having at least a partial insensitive peripheral area of the retina.

20 Further, it is contemplated the ophthalmic lens may facilitate either a single vision prescription corrected lens or a bifocal vision prescription corrected lens or a non-prescription filtered enhancing eye wear to minimize ultraviolet rays. All refracted images through the lenses are real, normal full size 25 without compression or minification. With the ophthalmic lens system having a prescription corrected prismatic lens there is no eye rotation or scanning to locate the expanded field, therefore there is no diplopia. That is, a unified field of the image is disposed along the optical axis and/or the optical axis of the eye of 30 the patient to minimize diplopia. Except for bifocal or non-prism window lines there is substantially no prism lines visible on the lenses. The corrective prescription curvature may be formed on

the lens member on either the object or image side of the lens. A mold and method for manufacturing such lenses is also disclosed.

It is believed the problem of central vision impairment and blindness due to N.S.M.D. and other problems such as retinitis

5 pigmentosa (tunnel vision), glaucoma with constricted fields, hemianopia are substantially overcome by the prescription corrected prismatic eye glasses of this embodiment.

Eye wear incorporating the present lenses are unlike any of the various Galalean, Ocatech telescopes, amorphic lenses, Fresnel

10 prisms, small prisms, mirrors, buttons that are attached to a patient's normal prescription glasses. The fields provided by these optical aids are mon-ocular or have fields that are minified and require a patient to rotate their eye or scan their eye to look into a the small prism, button or mirror to view the enhanced field.

15 While scanning or rotating their eye to look into the field enhancing prism their other eye follows, thereby loosing sight of any fringe objects and creating a diplopia condition.

In contrast, with the present lenses there is no eye rotation or scanning required and there is no diplopia. The lenses are

20 refracted as single element lenses using standard trial frames or equivalent with standard trial test spheres to determine the best Rx value for each patient. For the present lenses all refracted images are real, normal and full size. There is no compression or minification of images.

25 In another embodiment, the image enhancing lens employs a lens member having a substantially conical base curvature. That is, the lens member may be configured in a substantially conical or frustum configuration, wherein an apex or upper plane defines the central non prism area and the plurality of prisms are located on

30 one of an inside or outside surface of the lens member. That is, in this embodiment, rather than disposing the plurality of prisms on a spherical base curve, a substantially conical or frustum lens

member is formed, wherein the apex of the lens member includes the clear aperture and the prism bases are spaced from the central aperture.

In yet another embodiment, the image or object side of the
5 lens member include an aspheric curvature. Again, the integral
prisms are disposed in an apex in, base out orientation to
circumscribe the central non prism area. The prisms may be
located on either the object or the image side of the lens member.

Brief Description of the Drawings:

10 Figure 1 is a cross sectional view of a first embodiment of
the prismatic lens.

Figure 2 is a cross sectional view of a second embodiment
of the prismatic lens.

15 Figure 3 is a top plan view of a lens having a plurality
of integral six diopter prisms.

Figure 4 is a cross sectional view taken along lines 4-4 of
Figure 3.

Figure 5 is an enlarged top plan view of a single prism of
the lens of Figure 3.

20 Figure 6 is a top plan view of mold for forming a six
diopter lens.

Figure 7 is a cross sectional view taken along lines 7-7 of
Figure 6.

25 Figure 8 is a top plan view of a lens having a plurality
of integral eight diopter prisms.

Figure 9 is a cross sectional view taken along lines 9-9 of
Figure 8.

Figure 10 is an enlarged top plan view of a single prism of
the lens of Figure 8.

30 Figure 11 is a top plan view of mold for forming an eight
diopter lens.

Figure 12 is a cross sectional view taken along lines 12-12 of Figure 11.

Figure 13 is a top plan view of a lens having a plurality of integral ten diopter prisms.

5 Figure 14 is a cross sectional view taken along lines 14-14 of Figure 13.

Figure 15 is an enlarged top plan view of a single prism of the lens of Figure 13.

10 Figure 16 is a top plan view of mold for forming a ten diopter lens.

Figure 17 is a cross sectional view taken along lines 17-17 of Figure 16.

Figure 18 is a top plan view of a lens having a plurality of integral twelve diopter prisms.

15 Figure 19 is a cross sectional view taken along lines 19-19 of Figure 18.

Figure 20 is an enlarged top plan view of a single prism of the lens of Figure 18.

20 Figure 21 is a top plan view of mold for forming a twelve diopter lens.

Figure 22 is a cross sectional view taken along lines 22-22 of Figure 21.

Figure 23 is a side elevation schematic of a six diopter lens.

25 Figure 24 is a side elevation schematic of an eight diopter lens.

Figure 25 is a side elevation schematic of a ten diopter lens.

Figure 26 is a side elevation schematic of a twelve diopter lens.

30 Figure 27 is a cross sectional view of a lens mold for a six diopter lens.

Figure 28 is a top plan view along line 28-28 of Figure 27.

Figure 29 is a top plan view of a lens having a plurality of integral prisms.

Figure 30 is a cross sectional view taken along line 30-30 of Figure 29.

5 Figure 31 is an enlarged top plan view of a single prism of the lens of Figure 29.

Figure 32 is a top plan view of a mold for forming a lens having a multitude of integral prisms.

10 Figure 33 is a cross sectional view taken along line 33-33 of Figure 32.

Figure 34 is a top plan view of a left trial test lens incorporating the image enhancing lens.

Figure 35 is a top plan view of a right trial test lens incorporating the image enhancing lens.

15 Figure 36 is a cross sectional view of a conical embodiment of the image enhancing lens.

Figure 37 is a cross sectional view of a conical embodiment of the image enhancing lens.

20 Figure 38 is a cross sectional view of a conical embodiment of the image enhancing lens.

Figure 39 is a cross sectional view of a conical lens and mold for forming prisms on an inner surface of the conical lens.

25 Figure 40 is a cross sectional view of another mold for forming a conical lens having a plurality of prisms on an inner surface of the lens.

Figure 41 is a top plan view taken along lines 41-41 of Figure 40.

Figure 42 is a cross sectional view of a conical lens in a lens mount.

Best Mode for Carrying Out the Invention:

Referring to Figures 1 and 2, an image enhancing lens 10 of the present invention is shown. The image enhancing lens 10 has an object side 12 and an image side 14, the light passing from the object side to the image side in normal operation of the lens. The lens 10 includes a lens member 30 having a multitude of integral and contiguous prisms 60 circumscribing a non prismatic area 90. The non prism area 90 is concentric with, or encompasses an optical center line of the lens member 30. Although the non prism area 90 is shown as a portion of the lens 10, it is understood the non prism area 90 may be formed as an aperture in the lens member 30. The non prism area 90 may be formed as a clear non prismatic aperture without corrective or image modifying characteristics. Each prism 60 has a base 62 and an apex 72, wherein an apex portion of each prism is defined by a truncation 68 of the prism proximal to the apex 72, thereby separating the apex 72 from the remaining portion of the prism 60. The truncation 68 is at an interface with the non prism area 90. Preferably, the prisms 60 are integrally formed with the lens member 30 to surround or circumscribe the central non prism area 90. Although some of the present embodiments are described in terms of 360 integral and contiguous prisms 60, it is understood the number of prisms may range from 3 to over 360, such as 720, 1080 or more. In each embodiment, the prisms 60 are contiguous as they circumscribe the non prism area 90.

Each prism 60 is adjacent, contiguous with or contacting two other prisms to encompass the non prism area 90. The lens 10 may incorporate a number of alternative design parameters including formation of the prismatic elements on the lens member 30 having a conical, spherical or aspheric base curvature. That is, the image enhancing lens 10 may be employed in a lens member 30, wherein at least one of the object and image sides

12,14 of the lens member is defined by a generally spherical base curvature, a generally conical base curvature, or an aspherical curvature. Further, the plurality of prisms 60 may be disposed on the object side 12 or the image side 14 of the lens 10. Within each 5 construction, the number of prisms 60 as well as the diopter of each prism may be varied depending upon design and application considerations.

Spherical Embodiment

In the spherical lens member embodiment, the image 10 enhancing lens 10 includes a lens member 30 having a front or object side 12 and a rear, image side 14. One of the object and image sides 12,14 includes a spherical base curvature and the remaining one of the object and image surfaces includes a plurality of integral, contiguous prisms 60 circumscribing the non prism 15 area 90. The configurations are shown wherein the non prism area 90 encompasses the optical axis of the lens 10 and has a circular periphery. Therefore, the size of the non prism area 90 may be described in terms of an area diameter.

As shown in Figures 3-26, the prisms 60 are designed to 20 have a base 62 and an apex 72. The prism 60 is initially designed to extend from the base 62 at the periphery of the lens member 30 to the apex 72 terminating at the optical axis of the lens member. In construction, the central area 90 is non prismatic and the prisms 25 60 are truncated at 68 at the periphery of the central area. That is, rather than terminating at an apex 72 at the optical center line of the lens member 30, the apex of the prism 60 is truncated so that the prism does not extend into the central area 90, and instead terminates at truncation line 68.

In a particular ophthalmic application of the lens 10, the 30 contiguous prisms 60 circumscribing the central area 90 are employed prescription corrected prismatic glasses for the visually

impaired and are true image enhancing lenses for low vision visually impaired patient. These glasses may be formed with or without bi focals.

In this configuration, the lens member 30 has a spherical

5 base curvature and is formed with 360 integral contiguous prisms 60 disposed about the central area 90. Depending upon the construction of the prisms 60, the lens 10 may be used for those who are visually impaired, or those having normal full sight merely requiring normal prescriptive correction.

10 For those lens to assist the visually impaired the prism diopters are between approximately 6 and 16, with a preferred range of between approximately six and fourteen diopters. The non prism central area 90 has a diameter between approximately 4 mm and 14 mm. It is contemplated these lenses 10 may assist

15 those suffering from age related macular degeneration, retinitis pigmentosa, glaucoma with open or constricted fields, macular degeneration, stargart's syndrome with macular degeneration, ushers syndrome with macular degeneration, hallgren's syndrome with macular degeneration, myopia, nystagmus, strabismus,

20 albinism, and pre operative cataract problems.

A distinct diopter of the contiguous prisms 60 allows the lenses 10 to be employed in prescription corrected prismatic vision enhancing glasses for the normally full sighted patient are true vision enhancing glasses, again with or without bifocals, and

25 provide approximately 25 per cent light transmission which brightens the images refracted onto the functional retina.

In a specific embodiment for the corrective lens for those of normal full sight, the lens 10 is a single element with a spherical base curvature, the prismatic lens again having 360, one degree

30 prisms 60 in an apex 72 in, base out 62 orientation circumscribing the central area 90. While the lens blank has a spherical curvature, the lens member 30 may be edged to accommodate off the shelf

ophthalmic lens holding frames. The diopters of the prisms 60 is between approximately two and four. The central non prism area 90 has a diameter between approximately twelve to sixteen millimeters, wherein preferred values are at approximately twelve, 5 fourteen and sixteen millimeters. This configuration may also be formed to include bi focals. The prismatic lenses 10 enhance the normal corrected vision by providing twenty five percent more transmissible light to the functional retina than conventional ophthalmic lenses. The increased light transmission provides a 10 brighter and sharper image to the functional retina and reduces or eliminates astigmatism.

These lens 10 may have application in medical diagnostic equipment, refractometers, phoropters, ophthalmoscopes and associated ocular lenses, goldman perimeters, fundus cameras, trial 15 test lenses, sporting telescopes and binoculars, optical manufacturing alignment equipment, optical lens bench testing equipment, microscopes, surveyors measuring scopes, camera lenses and axicon alignment equipment.

That is, in the spherical configuration, it is contemplated 20 the multitude of prisms 60, and specifically, 360 prisms are ground and polished on the optical base curve side of a mold 120, and then the lens blank is molded with all apexes 72 terminating towards the optical center line of the lens member 30. As stated, the prism 60 diopter range is 2, 4, 6, 8, 10, 12 and 14 to compensate for testing 25 and wearing the glasses for the various eye problems and normally full sighted patients as specified in the body of this patent.

The present glasses provide a unified refractive field and minimizes diplopia during there use by concentrating the unified field or images on the optical axis of the lens 10 as well as the 30 optical center of the patient's eye or optical center of their functional retina.

During the retraction, the functional retina is placed precisely in the non prism section of the lens 10. This precise alignment provides a full binocular vision with bifocals if required.

The present glasses are refracted and vision corrected for each

5 patient. There is no patient training required to accommodate wearing the present prescription corrected prismatic glasses. To the wearer, the lenses 10 feel and wear as any normal prescription glasses. Except for the bifocals, there are no noticeable lines to be observed, cosmetically they look like normal every day

10 prescription corrected eyeglasses.

The prisms 60 may be disposed on the image side 14 of the lens 10. Preferably, each of the prisms 60 has an equal size and exhibits an equal diopter. However, it is understood as discussed in the manufacture of the lenses 10, the diopter of the prisms 60

15 may be varied. The object side 12 of the lens 10 may be ground or formed to provide a prescriptive correction.

As shown in Figures 3-5, the prisms 60 may be formed with 6 diopters. The prisms 60 have a length of 37.5 mm from the apex 72 to the base 62, and sides of the prism contacting the

20 adjacent prisms sweep an arc of 1 degree. The base 62 has a length of 0.655 mm. An optical center line of the prism 60 bisects the length of the base and the angle formed by the converging sides. As formed with the lens member 30, the prisms 60 are truncated proximal to the apex 72 at truncation line 68.

25 Referring to Figures 6-7, a mold 122 for the six diopter lens is constructed so that the apex 72 of each prism terminates toward the optical axis of the lens member 30. Further, the apex portion 72 of the prism 60 is truncated at 68 at the periphery of the central area 90. The mold 122 may be formed so that the non prism area

30 90 has a diameter of 3, 4, 5, 6, 8, 10, 12, 14 or 16 mm. The central area 90 is centered about the optical axis of the mold 122. The surfaces of the mold 122 forming the prisms are optically polished

to 5 rings or better. The mold 122 has a diameter of 76 mm between bases of opposing prisms. The mold 122 has a height of 3.5 mm for the height of a prism base, with an overall diameter of 80 mm. The mold 122 may be formed of metal or glass, wherein 5 upon use of glass molds the preferred material is shott glass BK-7 or equivalent with a tolerance of +/- 0.10 mm.

As shown in Figures 8-10, the prisms 60 may be formed with 8 diopters. The prisms 60 have a length of 37.5 mm from the apex 72 to the base 62, and sides of the prism contacting the 10 adjacent prisms sweep an arc of 1 degree. The base 62 has a length of 0.655 mm. An optical center line of the prism 60 bisects the length of the base 62 and the angle formed by the converging sides.

Referring to Figures 11-12, a mold 124 for the eight diopter 15 lens 10 is constructed so that the apex 72 of each prism 60 terminates toward the optical axis of the lens member 30. Further, the apex portion of the prism 60 is truncated at a knife edge 68 at the periphery of the central area 90. The mold 124 may be formed so that the central area 90 has a diameter of 3, 4, 5, 6, 8, 10, 12, 14 20 or 16 mm. The central area 90 is centered about the optical axis of the mold 124. The surfaces of the mold 124 forming the prisms are optically polished to 5 rings or better. The mold 124 has a diameter of 76 mm between bases 62 of opposing prisms 60. The mold 124 has an overall diameter of 80 mm.

25 As shown in Figures 13-15, the prisms 60 may be formed with 10 diopters. The prisms 60 have a length of 37.5 mm from the apex 72 to the base 62, and sides of the prism contacting the adjacent prisms sweep an arc of 1 degree. The base 62 has a length of 0.655 mm. An optical center line of the prism 60 bisects 30 the length of the base 62 and the angle formed by the converging sides.

Referring to Figures 16-17, the mold 126 for the ten diopter lens 10 is constructed so that the apex 72 of each prism 60 terminates toward the optical axis of the lens member 30. Further, the apex portion of the prism 60 is truncated at a knife edge 68 at 5 the periphery of the central area 90. The mold 126 may be formed so that the central area 90 has a diameter of 3, 4, 5, 6, 8, 10, 12, 14 or 16 mm. The central area 90 is centered about the optical axis of the mold 126. The surfaces of the mold 126 forming the prisms 60 are optically polished to 5 rings or better. The mold 126 has a 10 diameter of 76 mm between bases 62 of opposing prisms 60. The mold 126 has an overall diameter of 80 mm.

As shown in Figures 18-20, the prisms 60 may be formed with 12 diopters. The prisms 60 have a length of 37.5 mm from the apex 72 to the base 62, and sides of the prism contacting the 15 adjacent prisms sweep an arc of 1 degree. The base 62 has a length of 0.655 mm. An optical center line of the prism 60 bisects the length of the base 62 and the angle formed by the converging sides.

Referring to Figures 21-22, the mold 128 for the twelve 20 diopter lens is constructed so that the apex 72 of each prism 60 terminates toward the optical axis of the lens member 30. Further, the apex portion of the prism 60 is truncated at a knife edge 68 at the periphery of the non prism area 90. The mold 128 may be formed so that the central area 90 has a diameter of 3, 4, 5, 6, 8, 10, 25 12, 14 or 16 mm. The central area 90 is centered about the optical axis of the mold 128. The surfaces of the mold 128 forming the prisms 60 are optically polished to 5 rings or better. The mold 128 has a diameter of 76 mm between bases 62 of opposing prisms 60. The mold 128 has an overall diameter of 80 mm.

30 Preferably, the lenses 10 are formed of an ophthalmic plastic, such as a CR-39 or equivalent, having an N value of 1.498 or better.

Figures 23-26 show the profile of lens blanks for lens member 30 and heights of prisms 60 for the six, eight, ten and twelve diopter configurations. The central area 90 is shown as 10 mm, however, it is understood the diameter of the central area may 5 be any of the previously recited dimensions. The diameter of the lens member 30 is shown as 60 to 80 mm, with a nominal radius from the edge of the central area 90 to the periphery of the lens member of 30.00 mm.

Specifically, as shown in Figure 23, in the six diopter 10 embodiment the base 62 of a prism 60 in the six diopter prism has a height, (length along the optical axis of the lens member 30), of 3.42 mm, an angle between the object side of the prism and the image side of the prism of 6 degrees, and a designed length of 32.5 mm from the apex 72 to the base.

15 Referring to Figure 24, in the eight diopter embodiment, the base 62 of a prism 60 in the eight diopter prism has a height, (length along the optical axis of the lens member 30), of 4.56 mm, an angle between the object side of the prism and the image side of the prism of 8 degrees, and a designed length of 32.5 mm from the 20 apex to the base.

As shown in Figure 25, in the ten diopter embodiment, the base 62 of a prism 60 in the ten diopter prism has a height, (length along the optical axis of the lens member 30), of 5.73 mm, an angle between the object side of the prism and the image side of 25 the prism of 10 degrees, and a designed length of 32.5 mm from the apex to the base.

30 Referring to Figure 26, in the twelve diopter embodiment, the base 62 of a prism 60 in the 12 diopter prism has a height, (length along the optical axis of the lens member 30), of 6.90 mm, an angle between the object side of the prism and the image side of the prism of 12 degrees, and a designed length of 32.5 mm from the apex to the base.

Figures 27-28 show a mold 130 for forming a prismatic lens 10 in an ophthalmic configuration. Specifically, the base curve of the mold 130 defines a dimension along the optical axis of 5.66 mm, and a 4 mm diameter central non prism area 90. The 5 surfaces forming the prisms are optically polished to 50 nanometers. The mold material may be copper OFHC coated with electroless nickel. Although the prism apexes 72 are designed to terminate at the optical axis of the lens member 30, the prisms 60 are truncated at 68 at the periphery of the central area 90 at a knife 10 edge. That is, the prisms 60 terminate at the periphery of the central area 90, but are designed as though extending to the optical axis of the lens member 30.

As shown in Figures 29-31, the lens member 30 has a diameter of 80 mm and includes integral, contiguous 12 diopter 15 prisms 60. Though the prescription curve is shown on the object or front side 12 of the lens 10, it is understood the prescription curve may be formed on the image or rear side 14 of the lens member 30 with the prisms formed on the object or front side. In the shown configuration, the lens member 30 is formed with the 20 base spherical curvature on the image, rear side 14 of the lens 10, with the 360 prisms 60, each prism sweeping on degree, wherein the base of the 12 diopter prism has a dimension of approximately 6.9 mm along the optical axis of the lens member, a clear area 90 having a 4 mm diameter, and a thickness of the clear area of 2.00 25 mm along the optical axis of the lens. A given prism 60 has a distance from the apex 72 to the base 62 of 40 mm and the converging sides that contact the adjacent prisms sweep an angle of 1 degree. The base 62 thus has dimension of 0.698 mm. The lens 10 is preferably formed of ophthalmic plastic, CR-39 or 30 equivalent having an N value of 1.498 or better. Further, all the surfaces through which an images passes must meet the optical

requirement of the American National Standards for ophthalmic plastic.

As shown in Figures 32-33, a mold 132 for forming the prismatic lens member 30 is disclosed. The mold 132 includes 5 surfaces for forming 360 integral prisms 60, wherein the apexes 72 of the prisms 60 are truncated at 68 to circumscribe the central area 90. The central area 90 has a diameter of 4 mm, the overall diameter is 85 mm, wherein the peripheral flange has a radius of 2.5 mm and the element has a thickness of 1.2 mm.

10 Referring to Figures 34-35, typical left and right field expanding trial test prisms 142, 144 for low vision refracting is disclosed. The particular diopter of the shown test set is six. However, it is understood the value may be any of those previously discussed. The test lens 142, 144 are sized to be retained within a 15 standard 38 mm sphere retainer ring 146, with the diopter and central aperture diameter stamped or marked on a handle of the set. The optical surfaces are polished.

In addition to the ophthalmic constructions, the prismatic lenses may be constructed without prescriptive correction surface.

20 That is, the increased light transmission by the prismatic lenses enhances the images of commercial imaging systems including telescopes and cameras.

Conical Embodiment

Referring to Figure 2, the conical embodiment is shown. In 25 the conical embodiment, the lens member 30 defines a frustum 150 having a first end 152 and a second smaller end 154. The frustum 150 has an outer surface 156, an inner surface 158, a cap 160 at a converging end 154 of the frustum. The cap 160 has an inner cap surface 162 and an outer cap surface 164. In the configuration 30 shown, the prisms 60 are formed on the inner surface 158, so that light passes from the open end 152 of the frustum 150 along the

converging length of the frustum to exit through the cap 160 in a parallel orientation. The light rays have a first density as they enter the conical lens, then as the light rays are converged and exit the lens through the smaller cap, the energy density is greater.

5 Again, in the design of lens 10, and mold, the virtual location of the prism apex 72 is beyond the cap 160. That is, a conical lens is formed, and a portion of the cone is truncated along a plane parallel to the base of the cone. Figures 37 and 38 also illustrate various configurations of the conical lens 10.

10 In the conical embodiment, the lens 10 is not a light pipe, but an actual optical lens having a controlled focus. The conical lens concentrates the light beam as it passes through the lens, thereby increasing the energy density of the beam. Preferably, the lens is totally internally reflective. A lens aperture in the cap 160
15 is used to control or regulate the diameter of the exiting beam. The cap 160 may be formed to function as a divergent lens, having a specific radius dictated by the intended operating environment. The specific diopter of the prisms 60 is selected to control the focus and focal length of the exiting beam, as required by ultimate
20 operating environment of the lens.

In the conical embodiment, the image enhancing lens 10 includes a lens member 30 having a conical base curvature, the plurality of integral prisms 60 on a surface of the lens member 30 and a central non prism area 90. The central area 90 is located at
25 the top of the frustum and includes the optical center of the conical lens member. The central area 90 may have a diameter as small as one thousandth of an inch. It is contemplated the area 90 may have a diameter up to 16 mm. As shown in Figures 36 and 39, the virtual prism apexes are designed to terminate at the optical axis of
30 the lens member 30 and beyond the end 154 of the frustum 150 and the cap 160. An angle between the optical axis of the lens

member 30 and the outer surface of the cone may range between 5 degrees to 85 degrees.

The prisms 60 may be disposed on the object side or the image side of the lens, as dictated by operating parameters. Each 5 prism 60 has a base 62 and a virtual apex 72 and a truncated line 68 where the prism terminates at truncation 68 at the periphery of the central area 90. Preferably, each of the prisms 60 has an equal size and exhibits an equal diopter. However, it is understood as discussed in the manufacture of the lenses 10, the diopters may be 10 varied. In a preferred construction, the lens member 30 has 360 prisms 60 disposed about the central non prism area 90, wherein each prism is truncated 68 at or adjacent the central non prism area and the base 62 of each prism is radially spaced from the central area to dispose the truncation 68 intermediate the base and the 15 central area.

A mold 136 for forming a conical lens 10 is shown in Figure 39. The mold 136 has a multitude of prism forming surfaces that define the inner surface 158 of the finished lens. The mold 136 forms a conical cavity which is filled with the lens 20 material, and the outer surface 164 of the cap may be subsequently radiused as dictated by the intended operating environment. The virtual convergence of the prism apexes 72 is shown by the dotted lines extending above the cap 160. Figure 36 also shows the virtual convergence of the prism apexes 72, and the truncation 68. 25 In the mold 136 for forming a conical lens 10, the conical mold 136 is formed with 360 prism forming facets to form the inner surface 158 of the lens. The mold 136 may be formed of copper OFHC coated with electroless nickel and optically polished to 50 nanometers. A pouring gasket is disposed about the mold 136 to 30 define the outer surfaces and a lens blank of CR 39 or poly carbonate or glass is disposed in the cavity. Although the present prismatic forming surfaces of the mold are selected to dispose the

prisms on the inner surface 158, the mold may be constructed to locate the prisms on the outer surface 156.

As shown in Figures 40-41, a mold 134 for the conical lens may be formed to dispose the prisms 60 on the inside surface 158

5 of a conical lens member 30. The mold 134 includes 360 prism forming surfaces, optically polished to 5 rings or better. The mold 134 defines a dimension along the optical axis between the central area 90 and a base 62 of a prism 60 of 6.9 mm, wherein the lens member 30 has a diameter of 80 mm. The apexes 72 are truncated
10 at a knife edge 68 at the periphery of the central area 90. The mold 134 is formed of copper OFHC coated with electroless nickel. The mold has prism forming surfaces that create a corresponding shape in the resulting lens that functions as a prism. The resulting number of prismatic elements in the lens is thus determined by the

15 In another configuration of the conical embodiment, the lens 10 has a nominal length of 18 mm and the angle between the optical axis of the lens member and the inner surface of the cone is 20 degrees. The prisms 60 are designed for a conical configuration having a height of 25 mm, wherein the final frustum has a height

20 of 18 mm. Therefore, for a one degree prism, the base of the cone has a diameter of 18.19 mm and the base of each prism has a length of 0.4365 mm. Each prism 60 thus extends along the periphery of the cap a distance of 0.122 mm. The cap 160 has a radius of 6 mm and a dimension along the optical axis of the lens 25 of 0.5 mm. The cone angle may be between 10 and 24 degrees, with the particular application employing a 20 degree conical angle. The cap 160 includes a central non prism area 90 having a diameter of 0.001 to 0.15 mm.

30 In a further configuration of the conical lens, the lens member 30 may have a height of 26 mm, a base diameter of 30 mm, a central area 90 diameter of 0.25 mm and a 30 degree angle between the optical axis and the inner surface 158.

Calculations for the distance between prisms 60 may be carried out for a conical lens having 360 one degree equal lateral prisms base out around the periphery of the lens member 30. The mold diameter is 80 mm with a base curve of 265 mm and a lens blank radius of 40 mm. For a conical prism having a 10 mm diameter central non prism aperture, each prism has a length about the circumference of the lens of 0.6984 mm. At the cap, as the prisms 60 are designed to converge beyond the cap, the prisms will occupy a peripheral distance about the cap. Specifically, for the 10 mm diameter cap, the truncation line 68 of each prism 60 occupies a length of 0.08730 mm. If the central aperture 90 were reduced to 4 mm, then the truncation line 68 for each prism would occupy a length of 0.03492 mm about the periphery of the aperture.

A primary difference between the conical versus the spherical radius lens is the applicability of the conical lens to telemetry versus the ophthalmic applications for the spherical body. The conical embodiment may be employed in bar code laser scanners, CD ROM readers/writers, computer imaging projection lasers, medical operating laser equipment, set up and alignment of computer and servo driven lathes, mills, optical grinding and polishing equipment, axicon star image alignment equipment, alignment of high production conveyor equipment including news paper conveyors, aerial photography cameras, laser gun sights and celestial navigation equipment.

Preferably, the number of prisms 60, diopter of the prisms, location of the prisms on the object or image side, and the conical angle are selected to pass a collected image from the prisms through the central aperture.

Referring to Figure 42, a typical conical lens assembly is shown. In the conical lens assembly, the frustum lens member 30 is disposed within a lens mount 180. The lens mount 180 may be a black anodized aluminum body sized to retain the lens 10.

Preferably, the lens mount 180 includes a 0.010 mm relief pocket 182 between a portion of the lens and the mount. The mount 180 also includes an exit aperture 184 through which the emerging light rays pass.

5 Aspheric Embodiment

In the aspheric embodiment, the image enhancing lens includes a lens member having an aspheric optical surface, the plurality of integral prisms 60 on a surface of the lens member 30 and a central non prism area 90. The central aperture includes the 10 optical center of the conical lens member. The central area 90 may have a diameter as small as one thousandth of an inch. It is contemplated the central area 90 may have a diameter up to 16 mm. Again, the prism apexes 72 are designed to terminate at the optical axis of the lens member 30, and the prisms are truncated at 15 68 to bound the non prism area. The prisms 60 may be disposed upon the object or the image side 12, 14 of the aspheric lens member.

Industrial Applicability

The present lenses, conical, spherical or aspheric 20 embodiments may be employed in either a contact lenses or eye glasses, wherein both the contact lenses and eye glasses employ a graduated or blended transition between adjacent prisms rather than a discontinuity between adjacent prisms. In addition, the interface between the apex portions and the non prism area may be 25 transitioned or blended.

The graduated or blended transition between the prisms defined by a radius of curvature between the adjacent contiguous prisms, or the prism and the adjacent surface of lens member 30. That is, the common edges of adjacent prisms 60 are substantially 30 blended together to become indistinguishable to both the wearer and the one seeing the lenses. Therefore, the lens 10 has a

continuous appearance rather than exhibiting distinction facets.

The radius defining the surface between adjacent prisms 60 may be between approximately 0.01 mm to 1000 mm. The transition or graduated portion may be formed intermediate adjacent prisms as

5 well as the prisms and the lens member, such as between the central aperture and the apex of a prism.

In a further embodiment, the blended transition is employed in a multiple diopter prismatic lens. Specifically, a prismatic lens includes a prismatic lens having a plurality of 10 contiguous prisms, at least two adjacent prisms having different diopters, and a blended surface transition between the adjacent prisms, the blended surface configured to substantially preclude the introduction of diplopia.

The present lenses may be made in a contact lens

15 configuration. In this configuration, the contact lenses include a single integral lens member having a front surface, a rear surface and a converging non-prism central portion for accommodating the normal central visual field of view, and at least one prism on the rear surface of the lens member, each prism having the apex and an 20 apex portion thereof contiguous with the converging non-prism portion and the base extending radially outwardly. Again, it is understood the prisms 60 may be formed on either the object or the image side of the lens member.

In a further embodiment, it is contemplated the prismatic 25 lens having the integral contiguous prisms circumscribing a central area may be disposed within a larger lens. That is, the prismatic lens member may form an island that itself is surrounded a larger lens member. Applications of such structure include bi focal corrective lenses, wherein the bi focal function is accomplished 30 through the prismatic lens within the larger corrective lens.

While preferred embodiments of the invention have been shown and described with particularity, it will be appreciated that

various changes and modifications may suggest themselves to one having ordinary skill in the art upon being apprised of the present invention. It is intended to encompass all such changes and modifications as fall within the scope and spirit of the appended 5 claims.

The following pages include ray traces and lens characteristics.

THE COMPUTER CODE V, THREE DIMENSIONAL RAY TRACE

The 360 lens system was computer designed using optical formulas derived from Snell's Law, ($n \sin i = n' \sin i'$) and from Dr.s Conready's and Kingslake's third order of optics which is incorporated into the EXCEL version 5.0 CODE V optical design program.

The following is a brief guide to the data included for each eye condition. The Code V output consists of lens drawings, lens construction parameters, indices of refraction, first order of lens properties, third order of aberrations using the various eye conditions, optical ray plots using the various eye conditions and spot diagrams.

The following areas of the 360 lens system were designed and/or checked using the CODE V three dimensional ray trace program

PHASE 1:

Calculation of Aran Safir's normal eye, used as a baseline for all other calculations

PHASE 2:

Calculations of a normal eye with a plus 1.75 diopter prescription correction

Calculations of a normal eye with a minus 1.75 diopter prescription correction

PHASE 3:

Aberrations and/or distortions calculations of a normal eye, used as a baseline all other aberration and/or distortion calculations

Calculations of the above eye conditions with the 360 prismatic correction lens

Calculations of powers of eye surfaces for plus or minus 6 diopters of prescription correction

Calculations of Chief ray location on retina and spot sizes for the various field of the relaxed and accommodated eye.

Calculations of image location change, if any, when wearing the 360 prismatic prescription corrected lenses, compared to the normal plus or minus prescription lenses for vertical 45 degree and other positions

PHASE 4:

Code V output for relaxed eye with the minus 6 diopter corrective lens

Code V output for relaxed eye with the minus 6 diopter, 360 prismatic prescription corrective lens

Code V output for accommodated eye with the plus 6 diopter corrective lens

Code V output for accommodated eye with the plus 6 diopter, 360 prismatic prescription corrective lens having a 6.4mm center thickness

Code V Output for accommodated eye with the plus 6 diopter, 360 prismatic prescription corrective lens having a 2.0mm center thickness

The 360° project will be analyzed using the model presented in this report. Figure 1 shows the general layout of the system. Figure 2 details the corrective lens/optical wedge portion. The eye model is illustrated in Figure 3. Tables 1 and 2 contain additional data for modeling this system.

The required angle of the optical wedges relates to the angular deviation of a prism and the definition of prism diopter. For a thin wedge of small angle in air, the angular deviation, δ , is given by $\delta = (n - 1) \alpha$, where α is the apex angle of the wedge and n is the refractive index of the prism material. A prism of 12 diopters displaces the incident light by 12 cm at a distance of 1 m. As a result, the apex angle of a 12 diopter prism is given by :

$$\alpha = [\tan^{-1} (0.12)] / (n - 1).$$

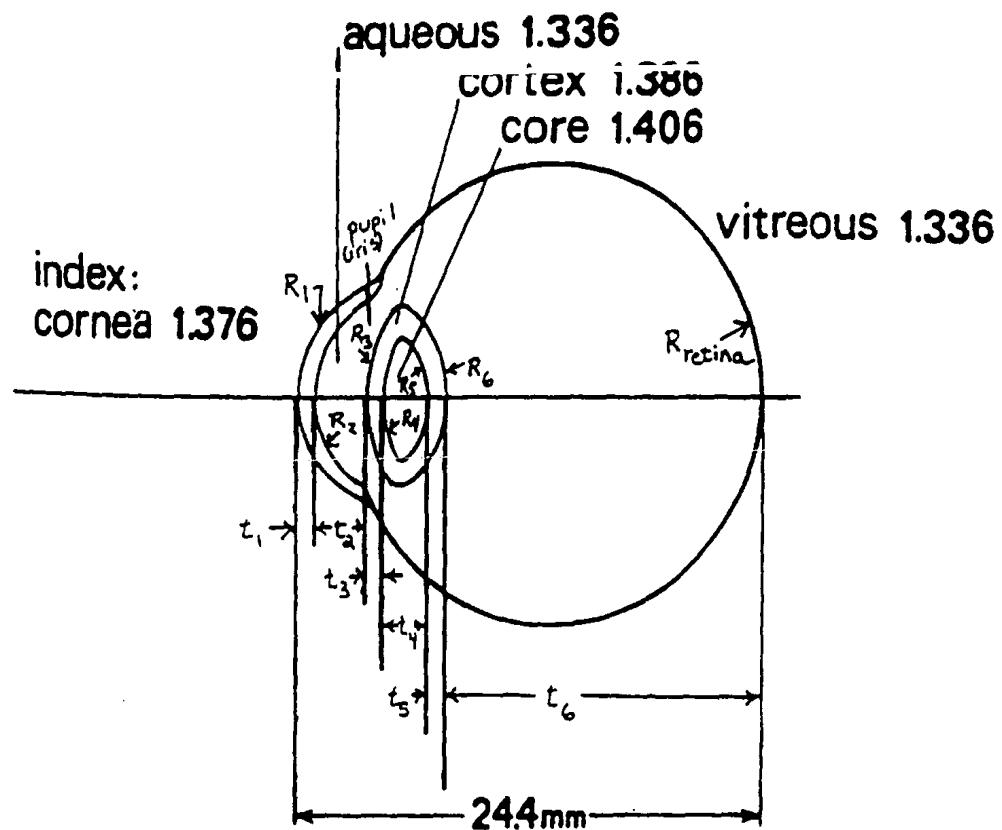
The corrective lens will include a central region of diameter, d , without optical wedges. This diameter will influence the edge thickness of the lens as shown in Figure 2.

The eye will be modeled using the data in Table 3-1 of Refraction and Clinical Optics by Aran Safir. This data is included here as Table 2. The curvature of the surface, thickness to the next surface, and index of refraction of the medium following the surface are taken from Safir's book and are listed as "standard eye." The power of each surface is computed, then the powers of adjacent surfaces are combined.

The thicknesses required to combine the lens core and cortex to calculate an equivalent lens power were estimated, then adjusted to agree with Safir's values.

To model the cases where the corrective lenses have ± 1.75 diopters of power, the eye must be adjusted. This is done by computing the necessary power of the eye such that the eye-lens combination is corrected to the power of the standard eye. The power of the eye will be altered by changing the curvature on the anterior surface of the cornea. Table 2 lists the data for the relaxed standard eye (from Safir) on page 6, followed by data for the eye requiring -1.75 diopters of lens correction (p. 7), data for the accommodated standard eye (p. 8), and data for the eye requiring $+1.75$ diopters of lens correction (p. 9). The items in italics appear on the schematic of Figure 3.

The iris serves as the aperture stop in this system. It is located at the anterior surface of the lens cortex. A pupil diameter of 5 mm is used for average light levels. The image surface in this system is the retina, which is curved. To approximate the curvature, the eye is considered a sphere. The radius of curvature of the retinal surface is taken as one half the length of the "standard" eyeball.



Schematic of eye. Values of radii and thicknesses given in Table 2.

Table 1. Data for 360° Project Ray Trace Model

Wavelength (nm)	589.3 (D light)
Field of View (degrees)	130° high by 2(18)° wide
Pupil Diameter (mm)	5
Lens diameter (mm)	65
Material for lens and wedges	CR-39, (n_p = 1.4985)
Apex angle of optical wedges (deg)	13.7267

Table 2. Powers of Eye Surfaces

	A	B	C	D	E	F	G	H	I
1 Notes:									
2 1. "A." denotes anterior surface of structure.									
3 2. "P." denotes posterior surface of structure.									
4 3. Retina is surface # 7 of the eye, and has curvature of 81.9672 (1/m)									
5									
6 RELAXED									
7 STANDARD EYE	Object	A. Cornea	P. cornea	A. lens cortex	P. lens core	P. lens cortex	P. lens core	P. lens cortex	P. lens core
8 Surface number	0	1	2	3	4	5	5	5	6
9 Curvature (1/m)	0.0000	129.8701	147.0588	100.0000	126.4063	-173.6111	-166.6667		
10 Radius of curv (mm)		7.7000	6.8000	10.0000	7.9110	-5.7600	-6.0000		
11 Thickness (m)	1E+12	0.0005	0.0031	0.0005	0.0024	0.0006	0.0006		
12 Thickness (mm)		0.5000	3.1000	0.5460	2.4190	0.6350	1.72E+04		
13 Index (after surt.)	1.0000	1.3760	1.3360	1.3860	1.4060	1.3860	1.3360		
14									
15 Power (diopters)	0.0000	48.8312	-5.8824	5.0000	2.5281	3.4722	8.3333		
16 Reduced Thickness (m)	1E+12	0.0004	0.0023	0.0004	0.0017	0.0005	12.8743		
17 Power of (diopters)		Cornea:	43.0532		lens core:	5.9852			
18					A. cortex + core:	10.9361			
19					equivalent lens	19.1141			
20					cornea + lens:	58.6379			
21									

Phase II Report

The standard model of the eye listed in the Phase I report was

stopped down to 2 mm to reduce the effects of aberrations in the eye. To compensate for the spherical aberration of the eye, an aspheric surface was added at the anterior surface of the lens cortex and optimized to yield zero third order spherical aberration at the retina. The curvature of the cornea was allowed to vary to maintain a constant length of the eyeball. These parameters were adjusted in both of the normal eyes and the eyes with corrective lenses. The values obtained for the eyes with the corrective lenses were used for the 360 wedge cases also.

Table 1 shows the chief ray (image) locations on the retina for the three scenarios of the relaxed eye: normal (no correction required), with -1.75 D corrective lenses, and with -1.75 D corrective lenses incorporating the 360 concept with 10 mm center aperture. Four object fields are analyzed, and the spot size at each is given. Figures 1 through 3 are spot diagrams for these three lenses. Each figure shows the size and shape of the image spot on the retina for the four fields points. The left axis lists the field positions both in fractional fields and in degrees. It does not give any information relating to the relative position of the spots on the retina.

The accommodated eye is detailed in Table 2. It lists the chief ray locations on the retina for the three scenarios of the accommodated eye: normal (no correction required), with +1.75 D corrective lenses, and with +1.75 D corrective lenses incorporating the 360 concept with 10 mm center aperture. Three object fields are analyzed, and the spot size at each is given. Figures 4 through 6 are spot diagrams for these three lenses.

In each of these cases, it is evident that the 360 lens deviates the light toward the center of the retina. While the spot shape does not change, the 360 lens produces a larger spot size than does the plain corrective lens. The 360 lens also produces a structured spot. Figure 7 shows the spot at a field location of (0, 40) degrees, which consists of 12 distinct lines. By tracing rays through the $\pm x$ edges of the apertures (see Fig. 8), the footprint of the ray bundle on the wedge surface can be obtained. In this case, its angular subtense is 11.85 degrees in the x-y plane. As a result, rays from this object will be spread over 12 of the 360 wedges, which is reflected in the structure of the spot diagram.

Table 2. Powers of Eye Surfaces

	A	B	C	D	E	F	G	H	I
1 Notes for Table 1:									
2	1. "A." denotes anterior surface of structure.								
3	2. "P." denotes posterior surface of structure.								
4	3. Retina is surface # 7 of the eye, and has curvature of 81.9672 (1/m)								
5									
57	ACCOMMODATED								
58	EYE REQUIRING +1.75 D CORRECTION								
59	Power of: (diopters)								
60	cornea: 43.18								
61	Ant surface: 48.96								
62	curv ant surf (1/m)	130.22							
63		Object	A. Cornea	P. cornea	A. lens cortex	P. lens core	P. lens cortex		
64	Surface number	0	1	2	3	4	5		
65	Curvature (1/m)	0.00001	130.2183	147.0588	187.6173	376.6478	-376.6478	-187.6173	
66	Radius of curv (mm)		7.6794	6.8000	5.3300	2.6550	-2.6550	-5.3300	
67	Thickness (m)	1E+12	0.0005	0.0027	0.0007	0.0027	0.0007	0.0007	17.2000
68	Thickness (mm)		0.5000	2.7000	0.6726	2.6550	0.6726	1.72E+04	
69	Index (after surf)	1.0000	1.3760	1.3360	1.3860	1.4060	1.3860	1.3360	
70									
71	Power (diopters)	0.0000	48.9621	-5.8824	9.3809	7.5330	7.5330	9.3809	
72	Reduced Thickness (m)	1E+12	0.0004	0.0020	0.0005	0.0019	0.0005	0.0005	12.8743
73	Power of: (diopters)		Comea:	43.1844		lens core:	14.9588		
74						A. cortex + core:	24.0809		
75						equivalent lens	33.0452		
76						cornea + lens:	70.6800		

Table 2. Powers of Eye Surfaces

	A	B	C	D	E	F	G	H	I
1	Notes for Table 1:								
2	1. "A" denotes anterior surface of structure.								
3	2. "P" denotes posterior surface of structure.								
4	3. Retina is surface # 7 of the eye, and has curvature of 81.9672 (1/m)								
5									
6									
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14									
15									
16									
17									
18									
19									
20									
21									
22	RELAXED								
23	EYE REQUIRING -1.75 D CORRECTION								
24	Power of: (diopters)								
25	cornea: 43.28								
26	Ant surface: 49.06								
27	curv ant surf (1/m) 130.48								
28	Object	A. Cornea	P. cornea	A. lens cortex	A. lens core	P. lens core	P. lens cortex	P. lens core	P. lens cortex
29	Surface number 0	1	2	3	4	5	6	7	8
30	Curvature (1/m)	0.0000	130.48343	147.0588	100.0000	126.4063	-173.6111	-166.6667	-166.6667
31	Radius of curv (mm)	7.6638	6.8000	10.0000	7.9110	-5.7600	-6.0000	-6.0000	-6.0000
32	Thickness (m)	1E+12	0.0005	0.0031	0.0005	0.0024	0.0006	17.2000	17.2000
33	Thickness (mm)	0.5000	3.1000	0.5460	2.4190	0.6350	1.72E+04	1.72E+04	1.72E+04
34	Index (after surf.)	1.0000	1.3760	1.3360	1.3860	1.4060	1.3860	1.3360	1.3360
35									
36	Power (diopters)	0.0000	49.0618	-5.8824	5.0000	2.5281	3.4722	8.3333	8.3333
37	Reduced Thickness (m)	1E+12	0.0004	0.0023	0.0004	0.0017	0.0005	12.8743	12.8743
38	Power of: (diopters)		Cornea: 43.2843						
39									
40									
41									

Table 1. Relaxed Eye.

Field points are (x angle, y angle) in degrees; chief ray is (x, y) location on retina in mm;
rms spot size is in microns.

Field point (0,0)	Standard eye	Eye & -1.75 D lens	Eye, lens, and wedges
chief ray	0,0	0,0	0,0
rms spot size	0.11	0.086	0.086
(0,60)			
chief ray	0,12.01	0,11.57	0,10.53
rms spot size	66.7	72.6	157.0
(40,40)			
chief ray	7.88,7.98	7.59,7.68	6.67,6.75
rms spot size	57.1	56.3	167.4
(75,0)			
chief ray	12.13,0	11.97,0	11.25,0
rms spot size	86.2	91.1	162.8

Table 2. Accomodated Eye.

Field points are (x angle, y angle) in degrees; chief ray is (x, y) location on retina in mm;
rms spot size is in microns.

Field point	Standard eye	Eye & +1.75 D lens	Eye, lens, and wedges
(0,0)			
chief ray	0,0	0,0	0,0
rms spot size	3.6	7.8	7.8
(0,40)			
chief ray	0.9,69	0,10.05	0,8.4
rms spot size	135.3	136.6	164.6
(30,30)			
chief ray	6.77,6.77	7.01,7.01	5.84,5.84
rms spot size	131.9	132.9	169.1

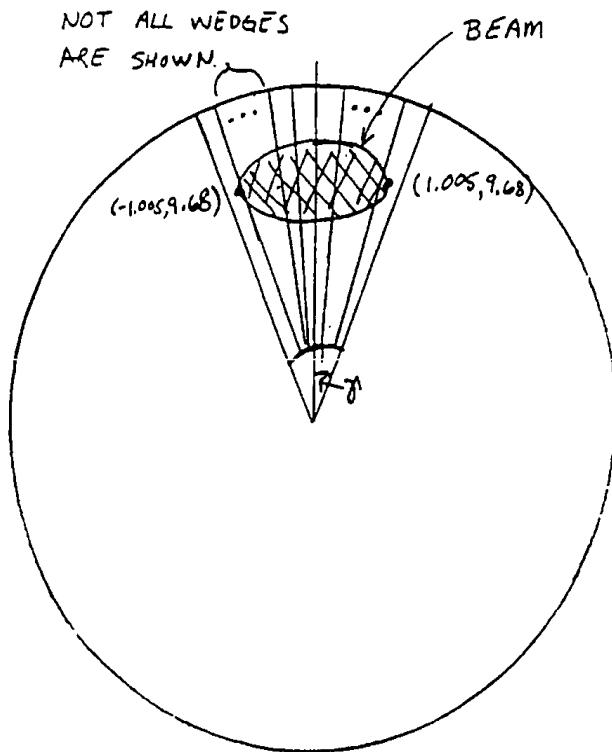


FIG 8. FOOTPRINT OF BEAM ON WEDGED SURFACE; RELAXED EYE, -1.75D CORRECTIVE LENS, 10 MM CENTER APERATURE.

$$\gamma = \tan^{-1}(1.005/9.68)$$

$$\gamma = 5.93^\circ$$

ANGULAR FOOTPRINT OF BEAM IN X DIRECTION = $2\gamma = 11.86^\circ$

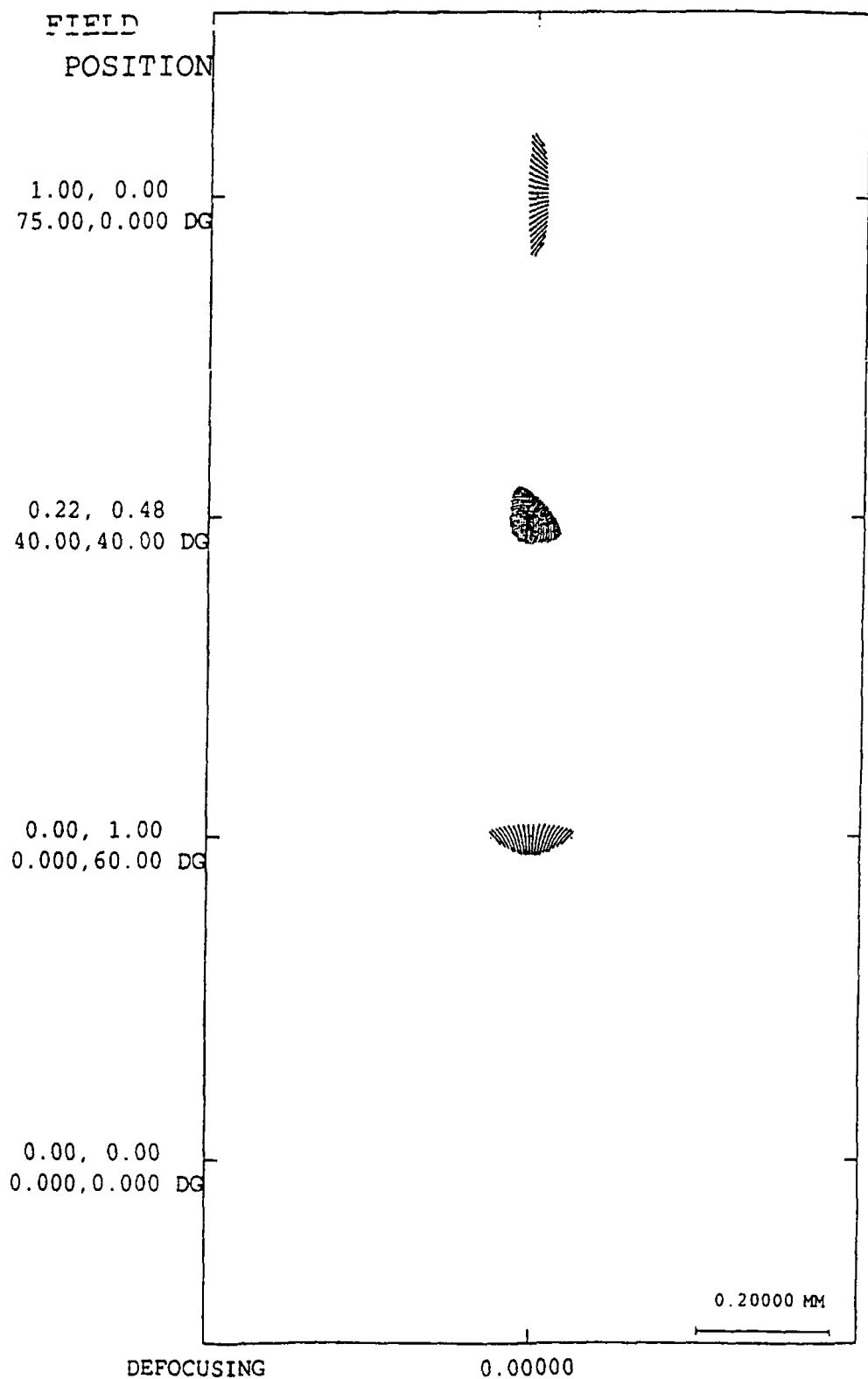


Fig. 1 Relaxed standard eye

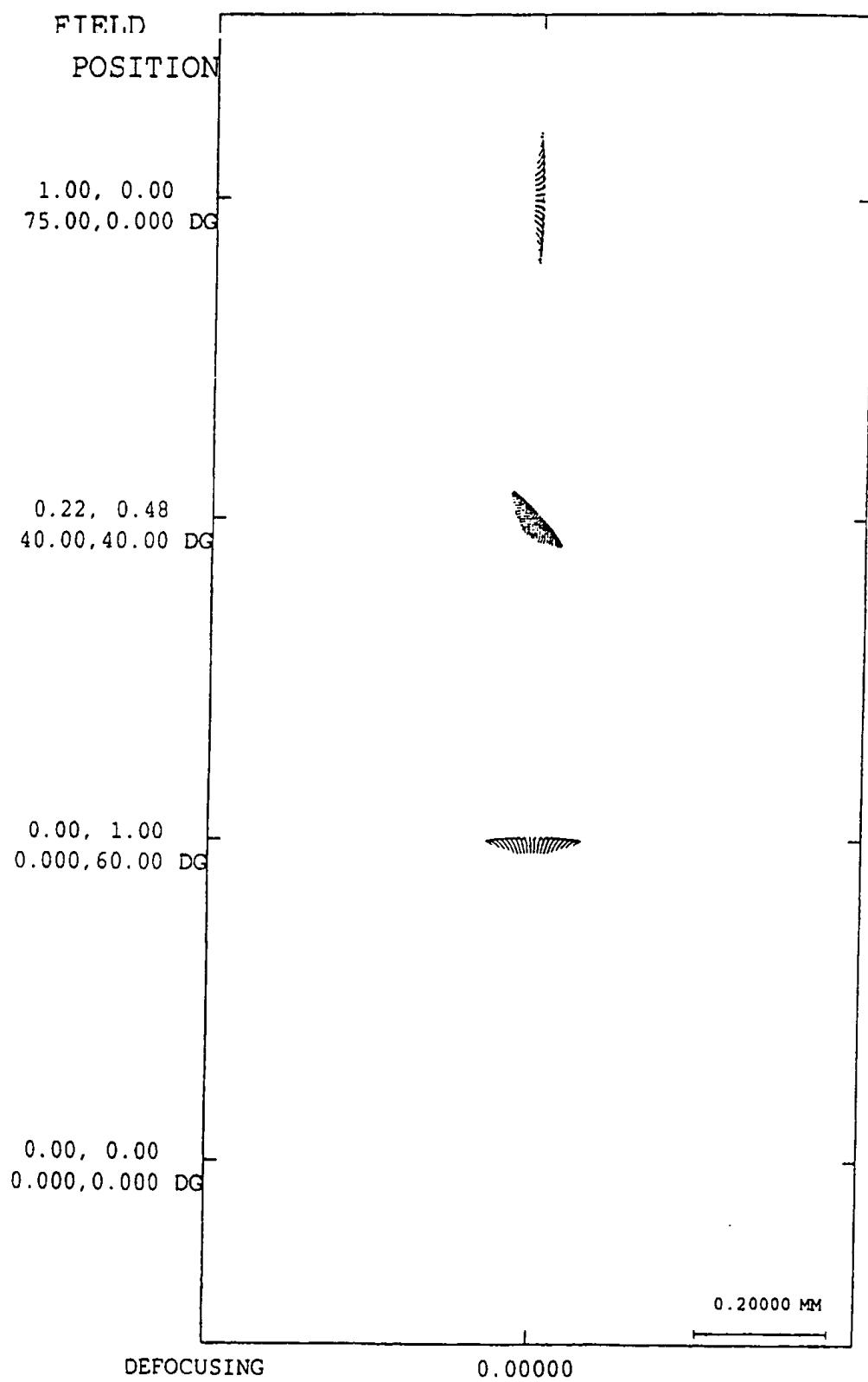


Fig. 2 Relaxed eye & -1.75 D lens

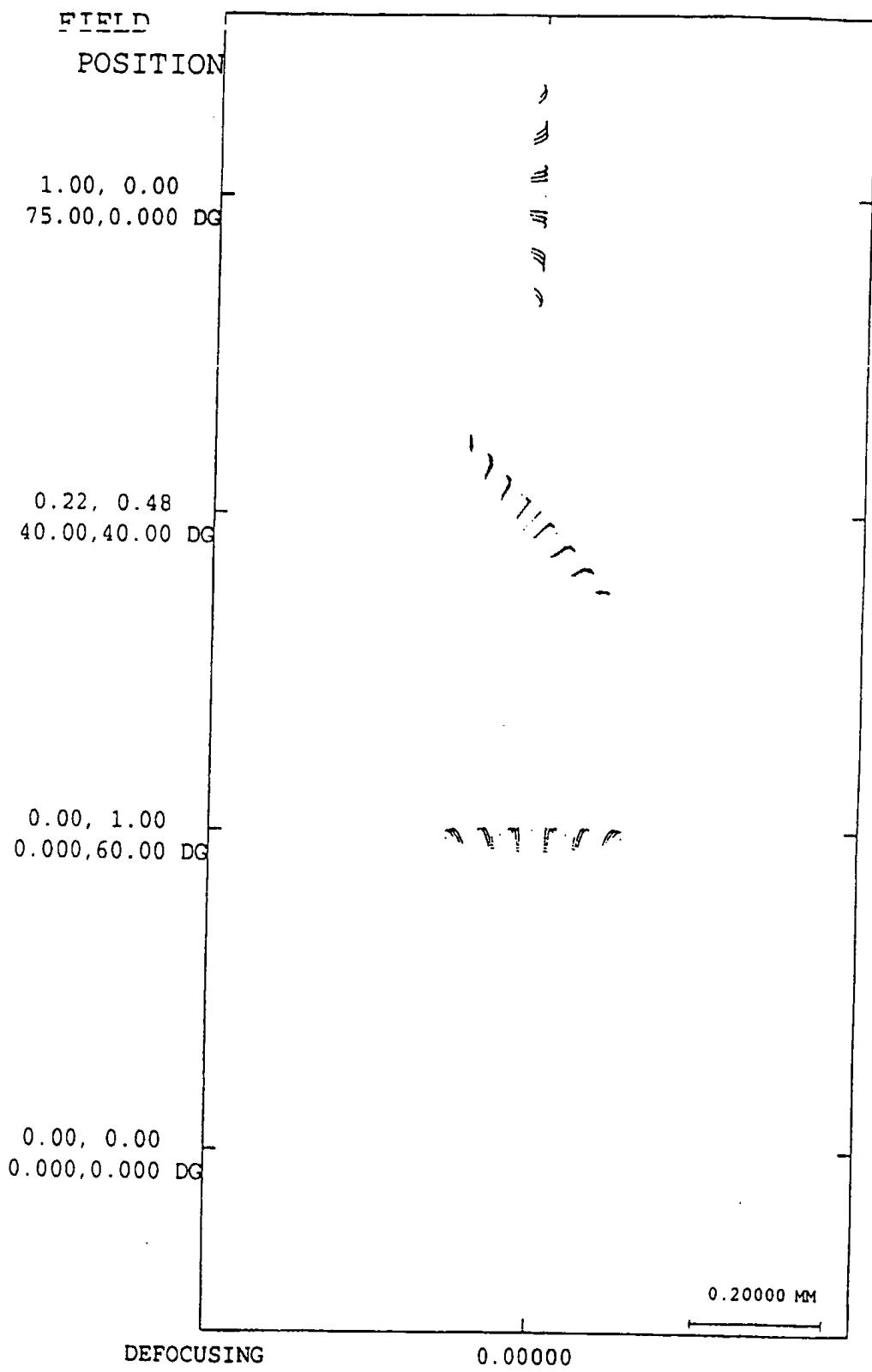


Fig.3 Relaxed 360, 10 mm CA

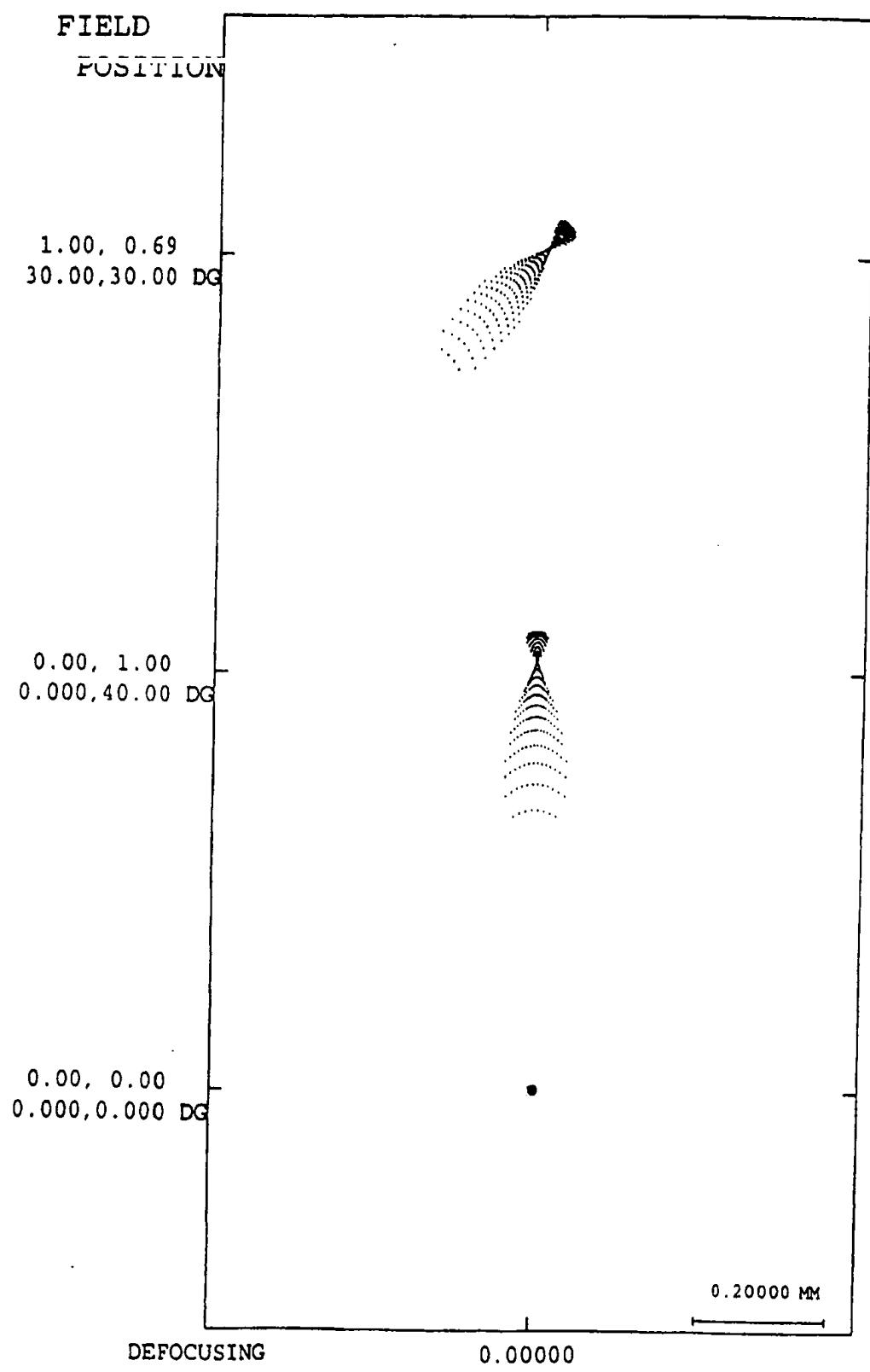


FIG. 4 Accommodated standard eye

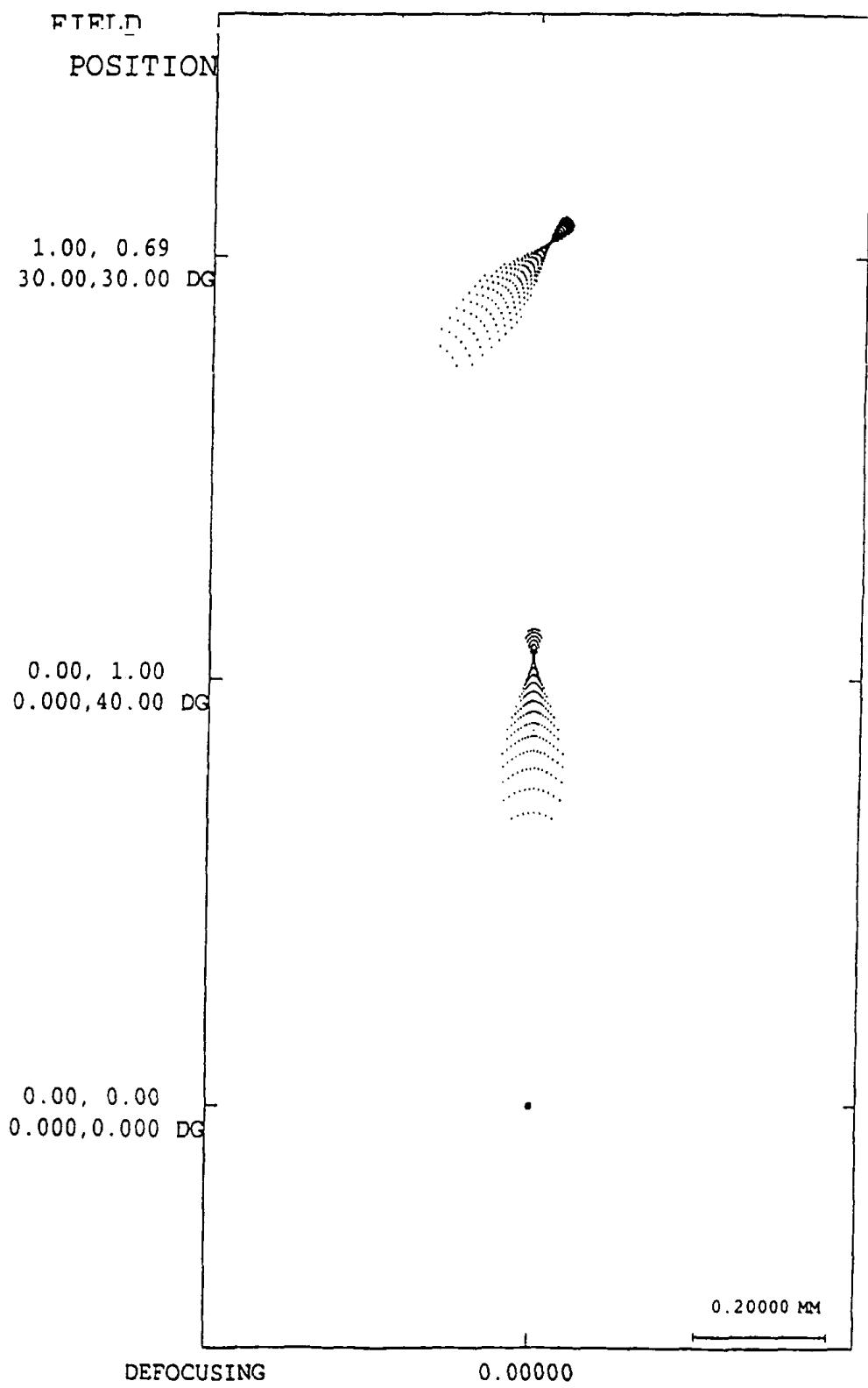


Fig. 5 Accommodated eye & +1.75D lens

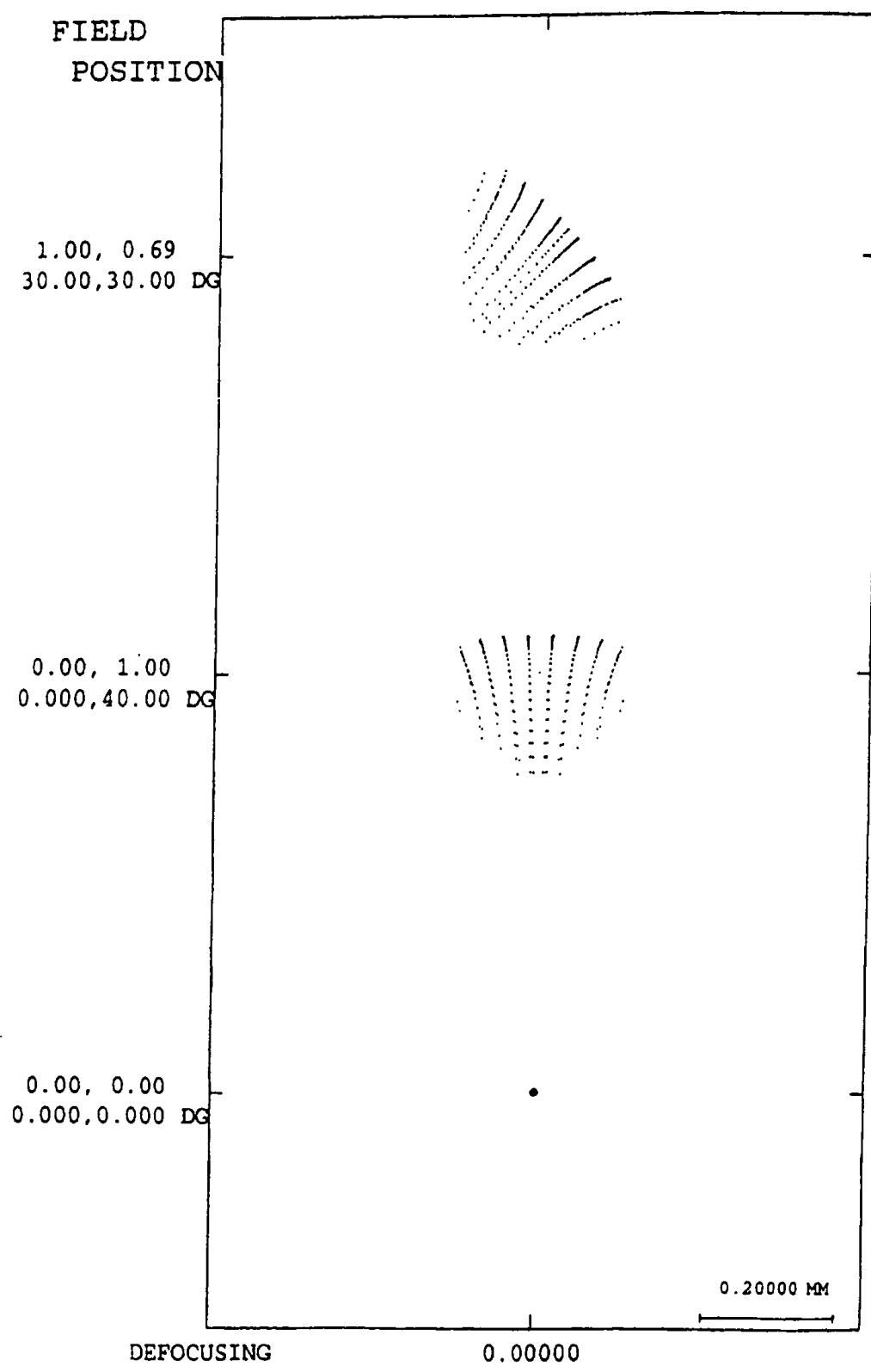


FIG. 6 Accommodated 360, 10 mm CA

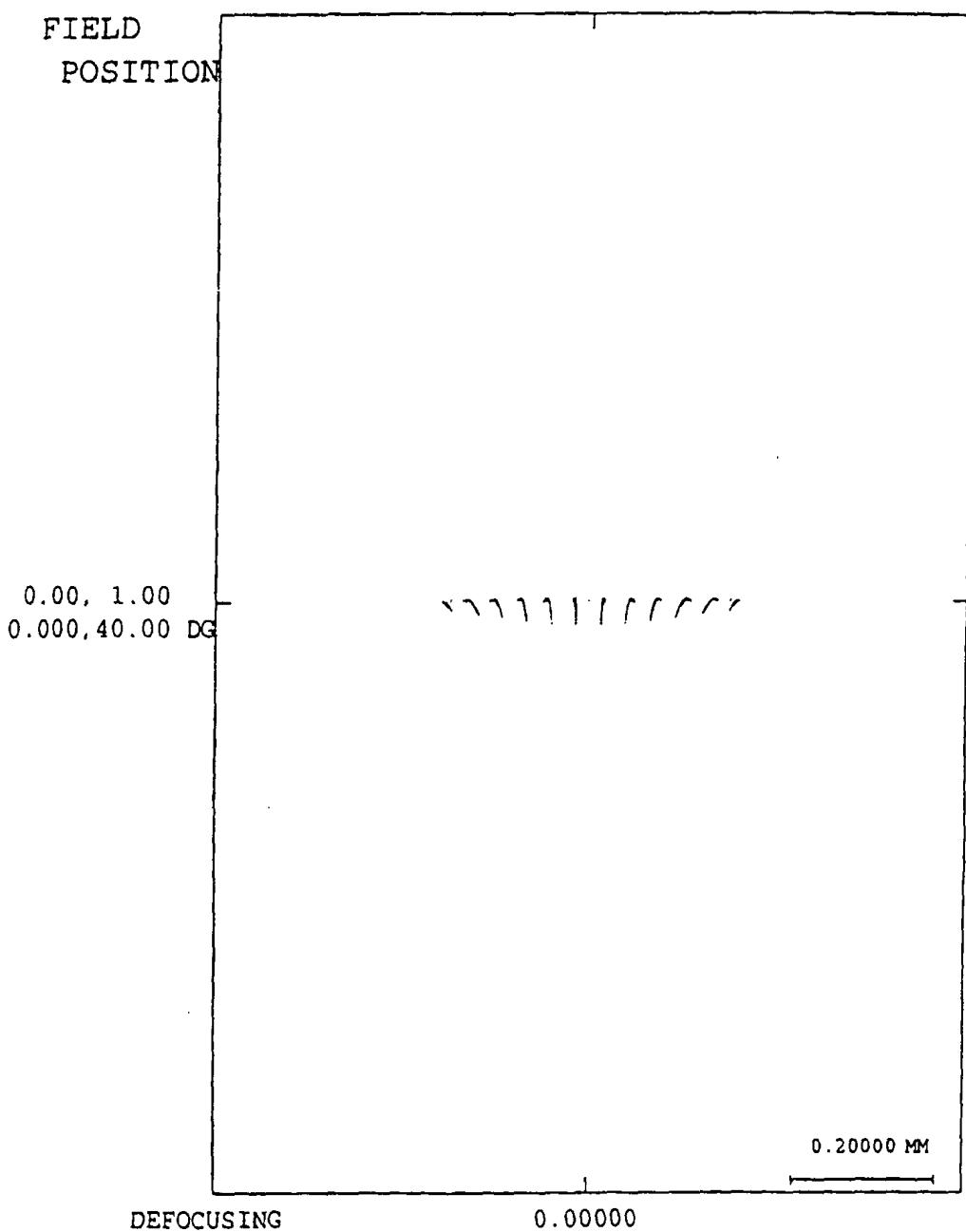


FIG. 7 Relaxed 360, 10 mm CA

Three systems are considered for both the relaxed and accommodated states of the eye: normal, with ± 1.75 D of correction, and with ± 1.75 D of correction and 360 twelve diopter prisms arranged about a central clear aperture of 10 mm.

For each system, similar output is produced. Tables 1 to 6 provide the following information for each of the systems analyzed: a brief listing of each system is given, including the curvature, thickness, and material for each surface. Next, the transverse third-order aberrations are listed for each surface, followed by the total for the entire system. In the output, the following abbreviations are used:

SA	spherical aberration
TCO	coma
TAS	tangential astigmatism
SAS	sagittal astigmatism
PTB	Petzval
DST	distortion.

The graphical output for each system consists of ray aberration plots, shown in figs. 1 to 6. A fan of rays defined along the x- or y-axis of the aperture stop is traced from each object position, and the deviation of each ray from the real chief ray position for that object point is calculated. The horizontal axis is the normalized aperture coordinate. On the left side of the graphs, the tangential (y) fans are shown; the vertical axis represents the y-coordinates of the departure of the rays from the chief ray. The right side of the figures show the sagittal (x) fans, and the vertical axis gives the x-coordinates of the ray departure. If rotational symmetry is present, only half of the sagittal fan is displayed. For the systems with the 360 wedges, a full sagittal fan is traced. In these cases, the tangential fan is smooth since the y fan is traced through a single wedge, and the sagittal fan is rippled since the x fan is traced through multiple wedges.

The effect of the 360 wedges on retinal image location is considered next. An object is defined by its position in space described by the vector sum of angular inclinations in the y-z plane (y-angle) and the x-z plane (x-angle), where z is the optical axis. Three linear objects are evaluated by tracing rays corresponding to a vertical line (x-angle = 0°, y-angle varies), a horizontal line (x-angle varies, y-angle=0°), and a 45° line (x-angle = y-angle). In each case the orientation was preserved, but the image location altered. Due to the symmetry of the system, the results for the horizontal line were identical to the results for the vertical line except that the x and y coordinates were reversed. Therefore, only data from the vertical line is shown. Tables 7 and 8 list the image location as a function of varying field angle for the three objects for the relaxed eye. The difference between the image height for the plain corrective lens and the corrective lens with 360 wedges is shown in figs. 7 and 8. The flat portion of the curve corresponds to objects imaged through the central clear aperture of the lens. Tables 9 and 10 and figs. 9 and 10 give the same information for the cases with the accommodated eye.

Table 2. Surfaces and Third Order Aberrations of Relaxed eye & -1.75 D lens

Lens data		RDY	THI	RMD	GLA
> OBJ:		INFINITY	INFINITY	AIR	
1:	-284.85700		2.000000	'CR39.'	
2:	INFINITY	15.000000		AIR	
3:	7.44060	0.500000		'CORNEA'	
4:	6.80000	3.100000		'AQUEOUS'	
STO:	10.00000	0.546000		'Cortex'	
ASP:					
K :	0.000000				
IC :	YES	CUF:	0.000000		
A :-.326088E-02		B :0.000000E+00	C :0.000000E+00	D :0.000000E+00	
6:	7.91100	2.419000		'CORE'	
7:	-5.76000	0.635000		'Cortex'	
8:	-6.00000	17.182294		'VITREOUS'	
IMG:	-12.20000	0.000000		AIR	
Third order aberrations					
	Position	1.	wavelength =	587.6 NM	
	SA	TCO	TAS	SAS	PTB
1	0.000000	-0.000126	0.095102	0.051064	0.029044
2	0.000000	0.000071	0.067903	0.022634	0.000000
3	-0.004725	-0.099805	-1.616013	-1.147575	-0.913356
4	0.000342	0.006911	0.126112	0.095091	0.079580
STO	-0.000027	-0.002004	-0.116845	-0.083718	-0.067155
ASP	0.007336	0.000000	0.000000	0.000000	0.000000
6	-0.000035	-0.002013	-0.070718	-0.045083	-0.032265
7	-0.000886	0.009946	-0.081536	-0.056721	-0.044314
8	-0.002012	0.019706	-0.176257	-0.133369	-0.111925
SUM	-0.000007	-0.067315	-1.772252	-1.297678	-1.060391
					-14.915030

Table 4. Surfaces and Third Order Aberrations of Accommodated standard eye

Lens data		RDY	THI	RMD	GLA
> OBJ:	INFINITY	400.000000			
1:	9.32496	0.500000		AIR	'CORNEA'
2:	6.80000	2.700000			'AQUEOUS'
STO:	5.33000	0.672500			'Cortex'
ASP:					
K :	0.000000				
IC :	YES	CUF:	0.000000		
A :-	701353E-02	B :0.000000E+00	C :0.000000E+00	D :0.000000E+00	
4:	2.65500	2.655000			'CORE'
5:	-2.65500	0.672500			'Cortex'
6:	-5.33000	17.182294			'VITREOUS'
IMG:	-12.20000	0.000000			AIR

Third order aberrations		Position 1,	Wavelength =	587.6 NM
SA	TCO	TAS	SAS	PTB
1	-0.002177	-0.036196	-0.370792	-0.237085
2	0.000423	0.004359	0.033571	0.023583
STO	-0.000948	-0.013177	-0.090499	-0.049786
ASP	0.016277	0.000000	0.000000	0.000000
4	-0.003810	-0.030709	-0.104969	-0.049960
5	-0.005786	-0.008612	-0.026729	-0.023880
6	-0.002635	0.006771	-0.035229	-0.031363
SUM	0.001343	-0.077564	-0.594647	-0.368493
				-0.255416
				-1.582584

Table 5. Surfaces and Third Order Aberrations of Accommodated eye & +1.75D lens

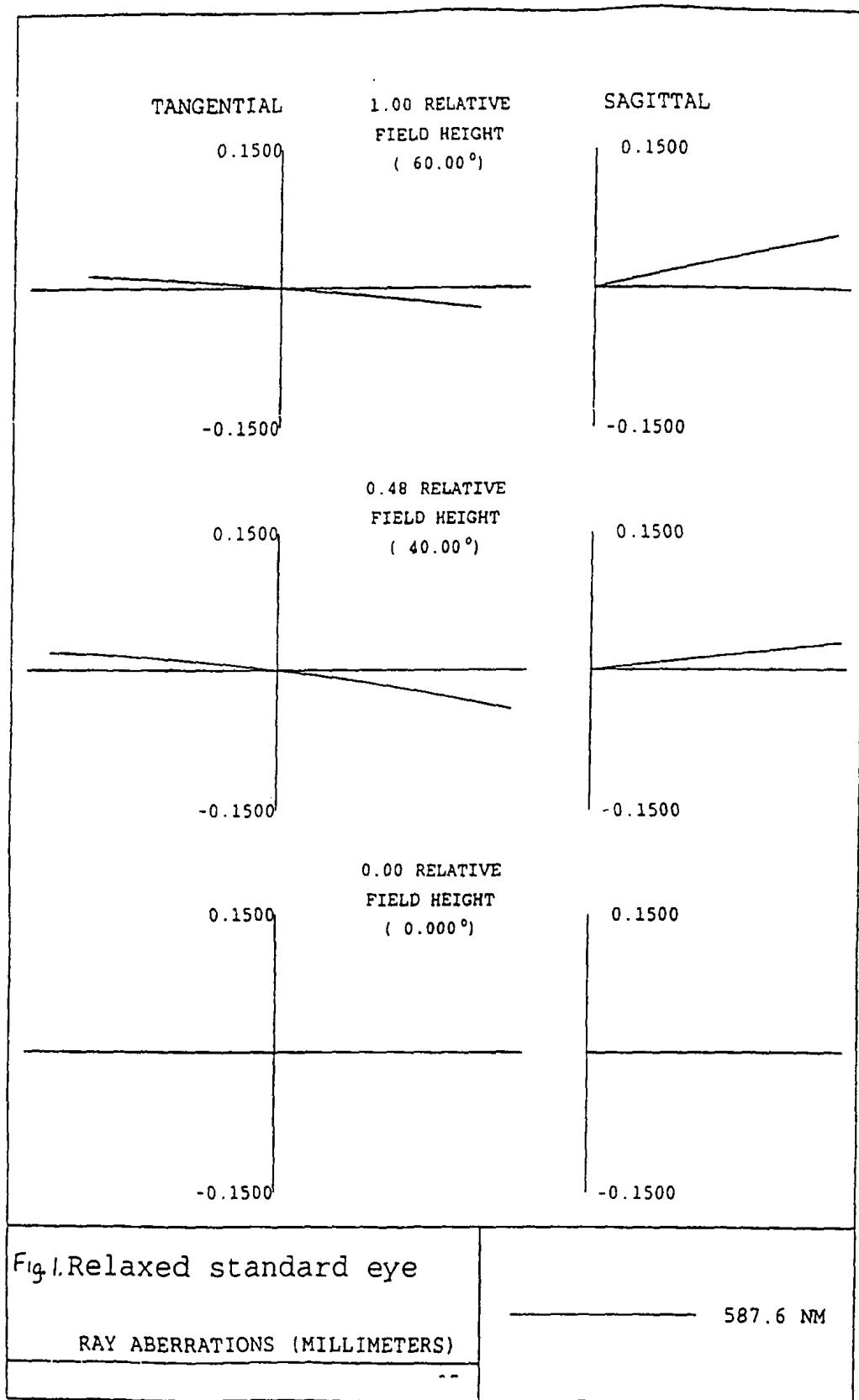
Lens data		RDY	THI	RMD	GLA
> OBJ:		INFINITY	400.000000	AIR	
1:	284.85700		2.000000	'CR39'	
2:	INFINITY		15.000000	AIR	
3:	9.80981		0.500000	'CORNEA'	
4:	6.80000		2.700000	'AQUEOUS'	
STO:		5.33000	0.672500	'Cortex'	
ASP:					
K :	0.000000				
IC :	YES	CUF:	0.000000		
A : - .633056E-02		B : 0.000000E+00	C : 0.000000E+00	D : 0.000000E+00	
6:	2.65500	2.655000		'CORE'	
7:	-2.65500	0.672500		'Cortex'	
8:	-5.33000	17.182294		'Vitreous'	
IMG:	-12.20000	0.000000		AIR	
Third order aberrations					
SA	TCO	Position 1, wavelength = 587.6 NM			
1	-0.000001	-0.00226	-0.037932	-0.017339	-0.007043
2	0.000000	0.000006	0.007325	0.002442	0.000000
3	-0.001606	-0.031099	-0.368731	-0.234904	-0.167991
4	0.000391	0.004279	0.034893	0.024496	0.019298
STO	-0.000879	-0.012946	-0.094149	-0.051751	-0.030553
ASP	0.013541	0.000000	0.000000	0.000000	0.000000
6	-0.003522	-0.030110	-0.109111	-0.051912	-0.023313
7	-0.005337	-0.008429	-0.027750	-0.024792	-0.023313
8	-0.002428	0.006621	-0.036572	-0.032559	-0.030553
SUM	0.000161	-0.071903	-0.632028	-0.386321	-0.263467
					-1.212438

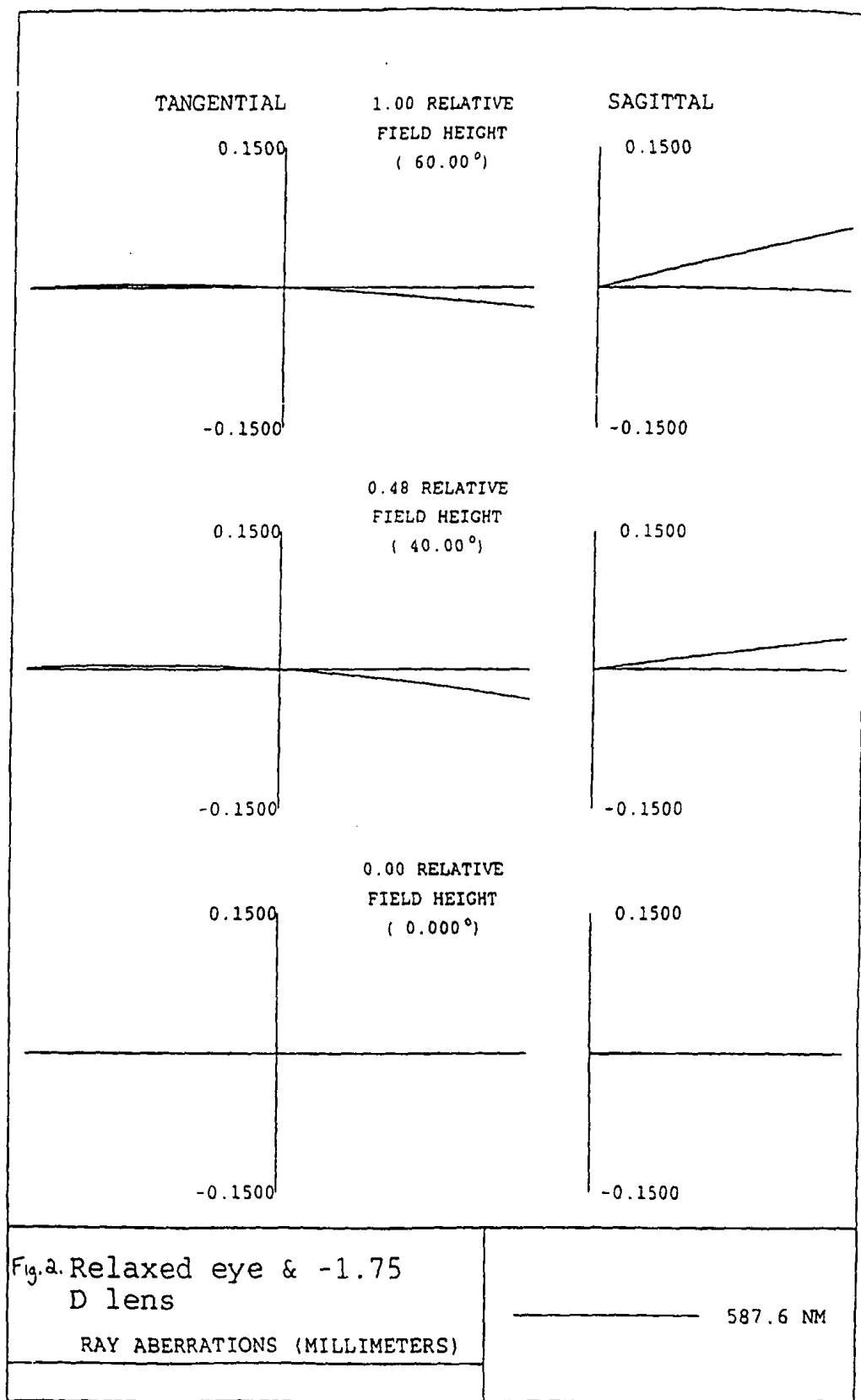
Table 6. Surfaces and Third Order Aberrations of Accommodated 360, 10 mm CA

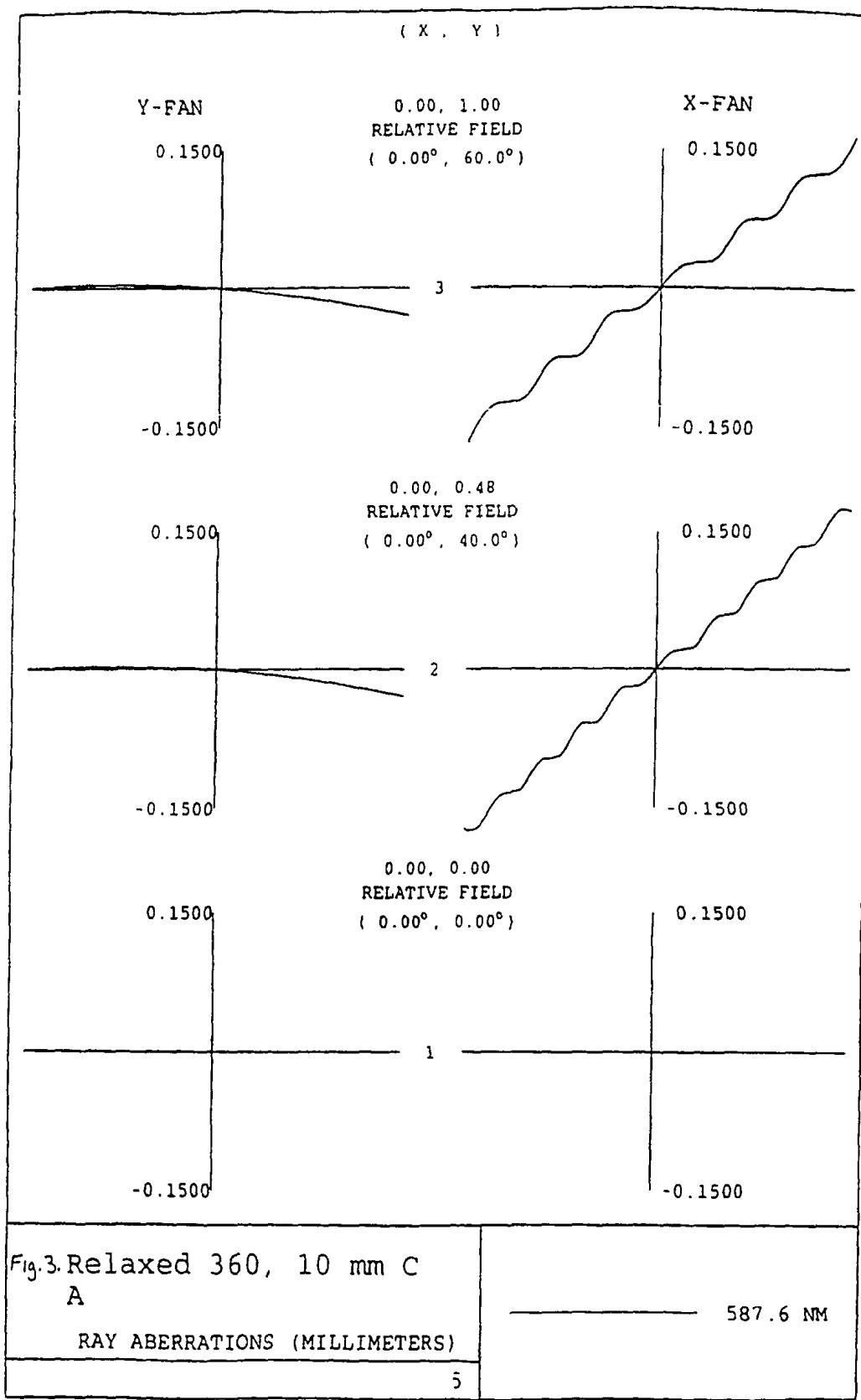
Lens data	RDY	TH1	RMD	GLA
> OBJ: INFINITY	400.000000			
1: 284.85700	2.000000		AIR	
2: INFINITY	15.000000		AIR	
UDS:				
IC : YES				
UCO				
C1 : 1.3727E+01	C2 : 6.5000E+01	C3 : 1.0000E+01		
C4 : 1.0000E+01				
3: 9.80981	0.500000		'CORNEA'	
4: 6.80000	2.700000		'AQUEOUS'	
STO: 5.33000	0.672500		'CORTEX'	
ASP:				
K : 0.000000				
IC : YES	CUF: 0.000000			
A : -633.056E-02	B : 0.000000E+00	C : 0.000000E+00	D : 0.000000E+00	
6: 2.65500	2.655000		'CORE'	
7: -2.65500	0.672500		'CORTEX'	
8: -5.33000	17.182294		'VITREOUS'	
IMG: -12.20000	0.000000	AIR		
Position 1, wavelength = 587.6 NM				
SA	TCO	TAS	SAS	PTB
1 -0.000001	-0.000223	-0.036875	-0.016856	-0.006847
2 0.000000	0.000006	0.007121	0.002374	0.000000
3 -0.001606	-0.030663	-0.358461	-0.228362	-0.163312
4 0.000391	0.004219	0.033922	0.023814	0.018760
STO -0.000879	-0.012765	-0.091527	-0.050310	-0.029702
ASP 0.013541	0.000000	0.000000	0.000000	0.000000
6 -0.003522	-0.029687	-0.106072	-0.050466	-0.022663
7 -0.005337	-0.008311	-0.026977	-0.024101	-0.022663
8 -0.002428	0.006528	-0.035554	-0.031652	-0.029702
SUM 0.000161	-0.070895	-0.614424	-0.375561	-0.256129
				-1.162186

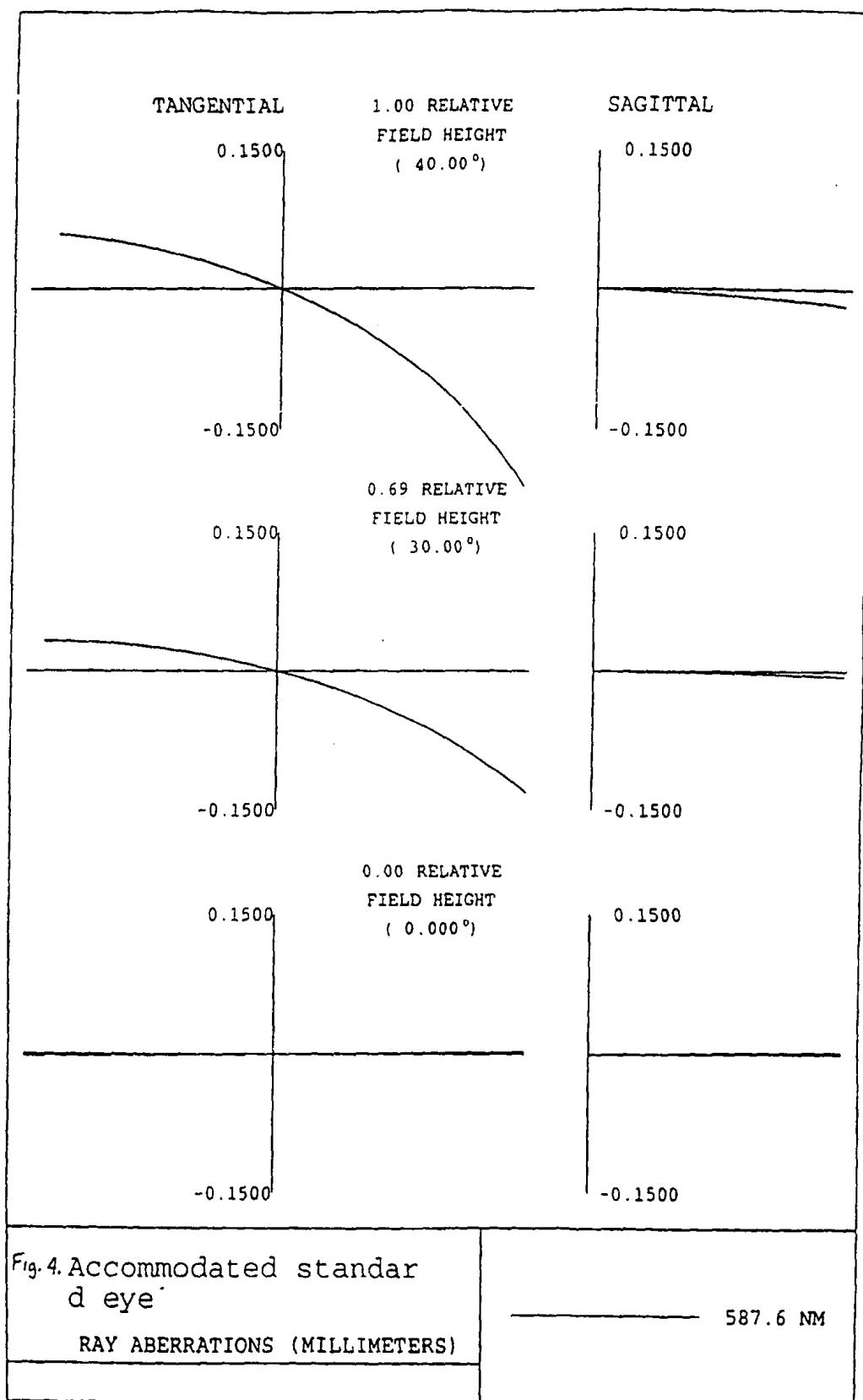
Table 3. Surfaces and Third Order Aberrations of Relaxed 360, 10 mm CA

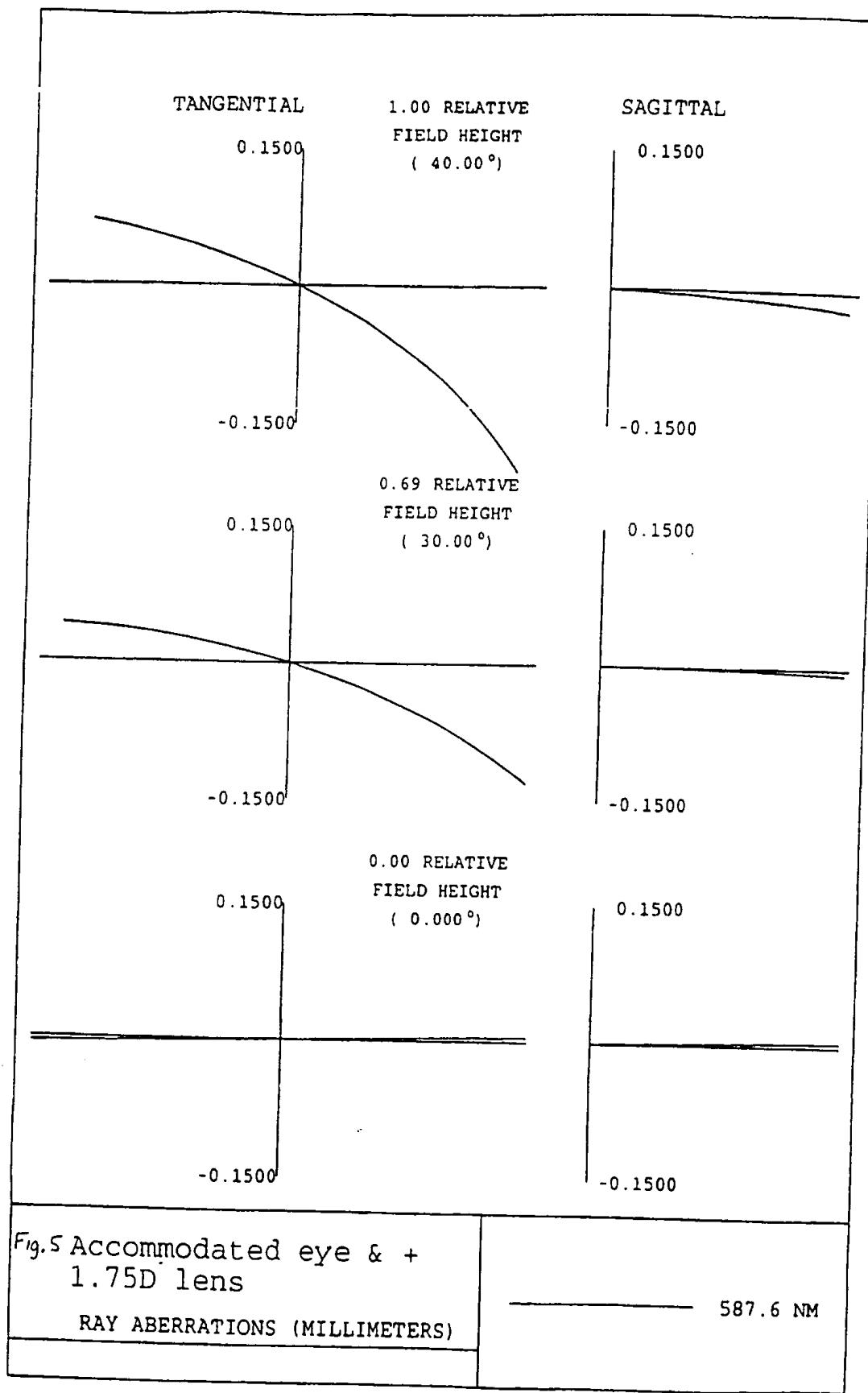
Lens data		RDY	THI	RMD	GLA
> OBJ:		INFINITY	INFINITY	AIR	
1:	-284.85700		2.000000	'CR39'	
2:		INFINITY	15.000000	AIR	
UDS:					
IC :	YES				
UCO					
C1 :	1.3727E+01	C2 :	6.5000E+01	C3 :	1.0000E+01
C4 :	1.0000E+01				
3:	7.44060	0.500000		'CORNEA'	
4:	6.80000	3.100000		'AQUEOUS'	
STO:	10.00000	0.546000		'CORTEX'	
ASP:					
K :	0.000000				
IC :	YES	CUF:	0.000000	C	: 0.000000E+00
A :	-326.088E-02	B :	0.000000E+00	D	: 0.000000E+00
6:	7.91100	2.419000		'CORE'	
7:	-5.76000	0.635000		'CORTEX'	
8:	-6.00000	17.182294		'VITREOUS'	
IMG:	-12.20000	0.000000		AIR	
SA	Position 1.	Wavelength =	587.6 NM	PTB	DST
1	0.000000	-0.000126	0.095102	0.051064	0.029044
2	0.000000	0.000071	0.067903	0.022634	-26.853410
3	-0.004725	-0.099805	-1.616013	-1.147575	0.000000
4	0.000342	0.006911	0.126112	0.095091	21.666562
STO	-0.000027	-0.002004	-0.116845	-0.083718	-0.913356
ASP	0.007336	0.000000	0.000000	0.000000	-8.079241
6	-0.000035	-0.002013	-0.070718	-0.045083	0.640293
7	-0.000886	0.009946	-0.081536	-0.056721	-2.075826
8	-0.002012	0.019706	-0.176257	-0.133369	0.000000
SUM	-0.000007	-0.067315	-1.772252	-1.297678	0.861077
				-0.111925	0.212267
				-0.435401	0.435401
				-1.060391	-14.915030











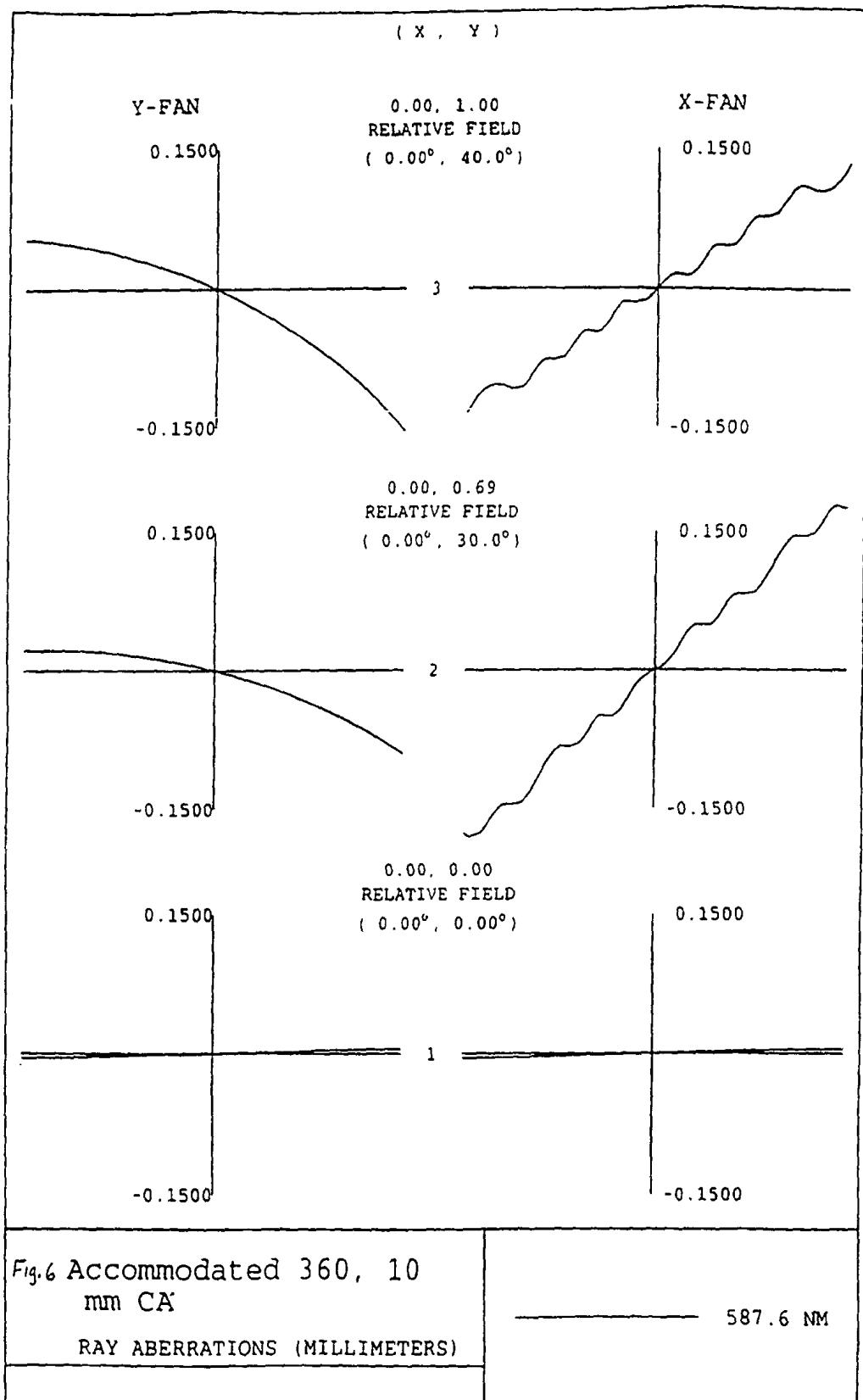


Table 7. Relaxed eye, vertical object

y angle (deg)	x image (mm)	Standard eye y image (mm)	-1.75 lens y image (mm)	360 lens y image (mm)
0	0	0	0	0
10	0	2.94305	2.8598	2.8598
30	0	8.07607	7.81576	6.0971
40	0	9.96325	9.61164	8.08038
50	0	11.2776	10.8519	9.55314
60	0	12.0051	11.57	10.5306

Table 8. Relaxed eye, 45° object

x, y angle (deg)	Standard eye x, y image (mm)	-1.75 lens x, y image (mm)	360 lens x, y image (mm)
0	0	0	0
10	2.88281	2.79987	2.79987
30	6.95647	6.71263	5.61852
40	7.96572	7.66518	6.74468
50	8.46647	8.15673	7.40932
60	8.6241	8.37914	7.77621

Table 9. Accommodated eye, vertical object

<u>y angle (deg)</u>	<u>x image (mm)</u>	<u>Standard eye y image (mm)</u>	<u>+1.75 lens y image (mm)</u>	<u>360 lens y image (mm)</u>
0	0	0	0	0
5	0	1.43376	1.47538	1.47538
10	0	2.84437	2.92789	2.92789
15	0	4.20938	4.33537	4.33537
25	0	6.72021	6.93381	5.08014
30	0	7.83038	8.0894	6.2975
35	0	8.82462	9.13008	7.40632
40	0	9.69269	10.0451	8.39723

Table 10. Accommodated eye, 45° object

<u>x, y angle (deg)</u>	<u>Standard eye x, y image (mm)</u>	<u>+1.75 lens x, y image (mm)</u>	<u>360 lens x, y image (mm)</u>
0	0	0	0
5	1.42632	1.46788	1.46788
10	2.78712	2.87018	2.87018
20	5.11258	5.27789	3.98617
25	6.02483	6.23027	4.99546
30	6.76545	7.00956	5.83566
35	7.34696	7.62714	6.51887
40	7.78823	8.09972	7.06359

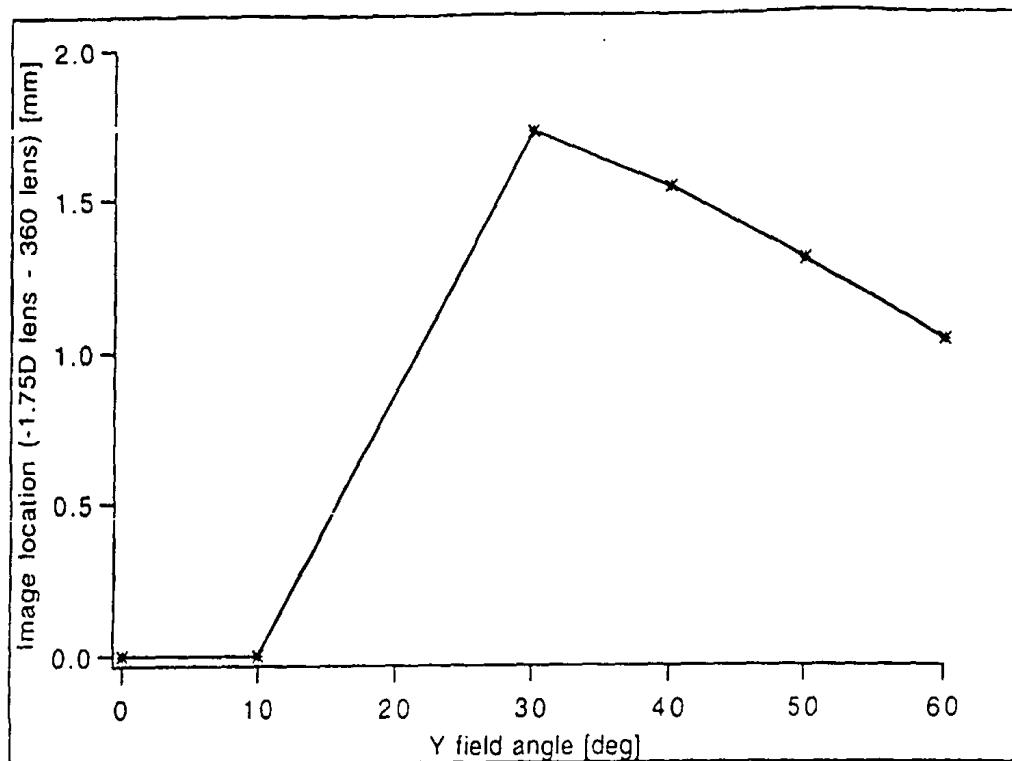


Figure 7. Change in image location for 360 lens on -1.75D corrective lens, relaxed eye, vertical object

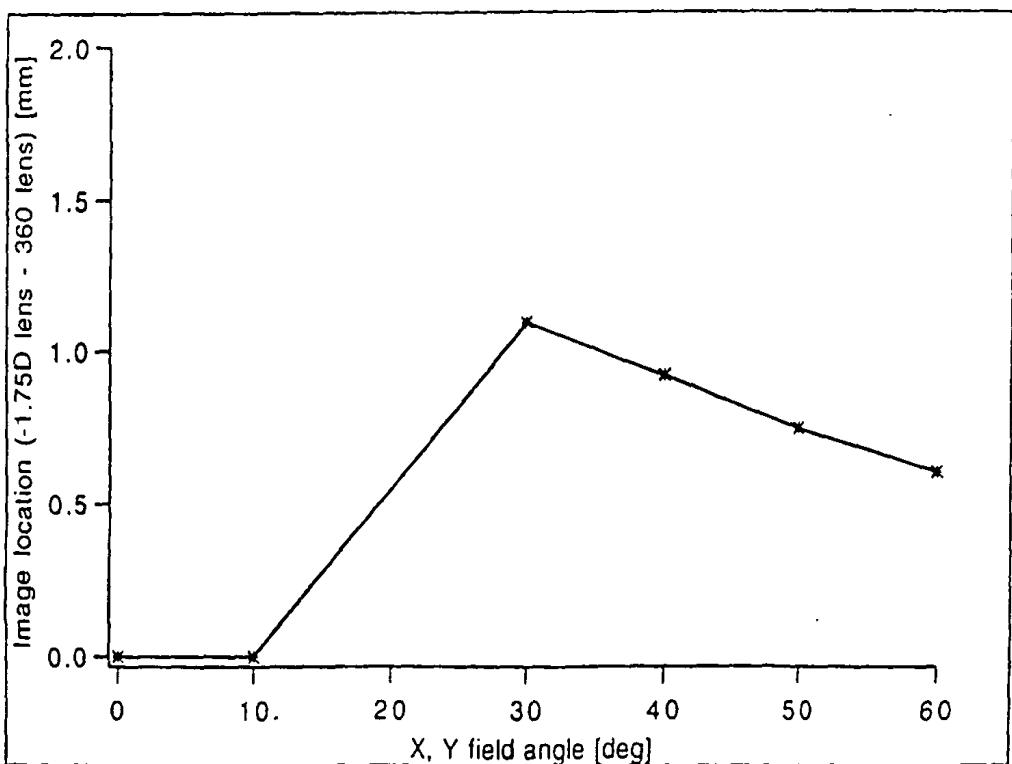


Figure 8. Change in image location for 360 lens on -1.75D corrective lens, relaxed eye, 45 ° object

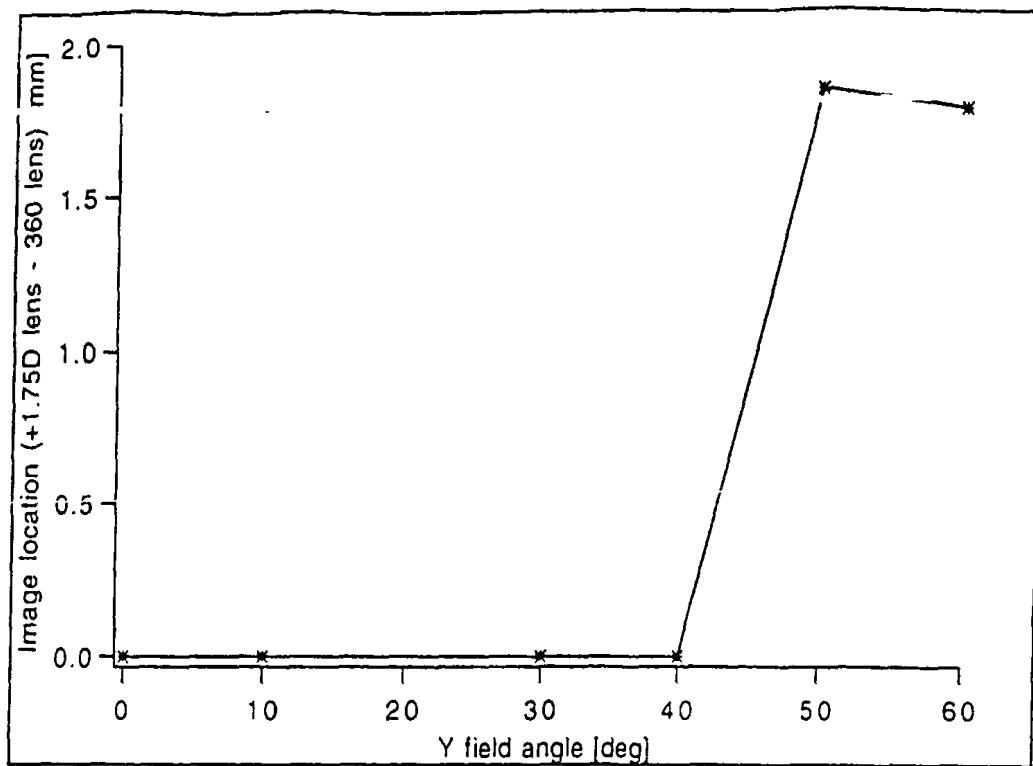


Figure 9. Change in image location for 360 lens on +1.75D corrective lens, accommodated eye, vertical object

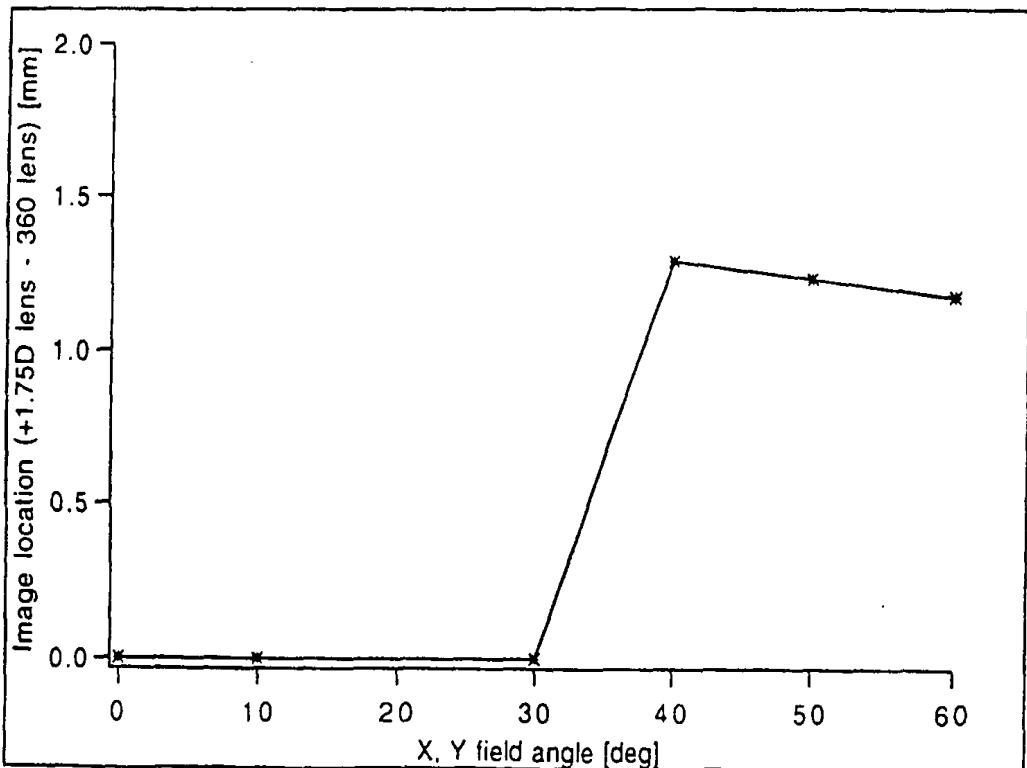


Figure 10. Change in image location for 360 lens on +1.75D corrective lens, accommodated eye, 45 ° object

This report analyzes the performance of the 360 design with corrective lenses of ± 6 D of power. As in the case of the ± 1.75 D corrective lenses, the following procedure was used to generate the lenses:

1. Calculate the radius of curvature on the corrective lens with a plano second surface by: $R[m] = (nCR-39 - 1)/Power [D]$.
2. Use the separated thin lens equation to calculate necessary power of eye to yield same total power for the eye plus lens combination as that of the standard eye. Estimate of necessary adjustment to anterior cornea curvature given by Excel spreadsheets shown as Tables 1 and 2.
3. Enter system into Code V and allow curvature of anterior cornea and aspheric coefficient of anterior lens cortex to vary. Optimize with field angles of 0° and 10° for third order spherical aberration equal to zero, and minimum weighted spot size.
4. Freeze all variables; this is the plain corrective lens. Add user-defined surface to the second surface of the lens for the 360 system.

The output generated is the same as that presented for the lenses with ± 1.75 D of corrective power which was given in the Phase II report and Phase III report. Descriptions of the output appear in those reports, as well as the User-Defined Surface subroutine which implements the 360 surface. Output in this report is given for the cases of the eye with the plain ± 6 D corrective lenses, and for the eye with ± 6 D corrective lenses incorporating the 360 surface. Data for the standard eye is not repeated here.

When the 360 surface is added to the lens, the thickness of the wedges permits the sag at the edge of the lens to be greater than the center thickness.

of the 360 concept on a + 6 D lens: with a center thickness of 6.4 mm, The spot size and structure is comparable. and does produce a greater deviation of the spot, focussing it closer to the center of the retina.

Table 1. Powers of Eye Surfaces for -6 D Lens

	A	B	C	D	E	F	G	H	I
1	Notes:								
2	1. "A." denotes anterior surface of structure.								
3	2. "P." denotes posterior surface of structure.								
4	3. Retina is surface # 7 of the eye, and has curvature of 81.9672 (1/m)								
5									
22	RELAXED								
23	EYE REQUIRING -6.0 D CORRECTION								
24	Power of: (dioplers)								
25	cornea: 43.31								
26	Ant. surface: 49.09								
27	curv. ant. surf. (1/m)	130.55							
28	Object	A. Cornea	P. cornea	A. lens cortex	P. lens core	P. lens cortex			
29	Surface number	0	1	2	3	4	5		
30	Curvature (1/m)	0.0000	130.54703	147.0588	100.0000	126.4063	-173.6111	-166.6617	
31	Radius of curv (mm)		7.6601	6.8000	10.0000	7.9110	-5.7600	-6.0000	
32	Thickness (m)	1E+12	0.0005	0.0031	0.0005	0.0024	0.0006	0.0112	
33	Thickness (mm)		0.5000	3.1000	0.5460	2.4190	0.6350	1.72E+01	
34	Index (after surf.)	1.0000	1.3760	1.3360	1.3860	1.4060	1.3860	1.3360	
35									
36	Power (dioplers)	0.0000	49.0857	-5.8824	5.0000	2.5281	3.4722	8.3333	
37	Reduced Thickness (m)	1E+12	0.0004	0.0023	0.0004	0.0017	0.0005	0.0129	
38	Power of: (dioplers)		Cornea: 43.3082						
39									
40									
41									

Table 2. Powers of Eye Surfaces for +6 D Lens

Tables. Powers of Eye Surfaces for ± 6D lenses

	A	B	C
6	RELAXED		
7	STANDARD EYE		
8	Surface number	Object	
9	Curvature (1/m)	0	
10	Radius of curv (mm)	0	
11	Thickness (m)	100000000000	
12	Thickness (mm)		
13	Index (aer. sur.)		
14			
15	Power (dioptr.)	0	
16	Reduced Thickness (m)	=C11/C13	
17	Power of: (dioptr.)		
18			
19			
20			
21			
22	RELAXED		
23	EYE REQUIRING -6.0 D CORRECTION		
24	Power of: (dioptr.)		
25		=(58.872-\$H\$19)/(1-\$H\$19*0.000573/\$E\$13)	
26		=(\$B\$25+\$E\$15)/(1-\$E\$15*\$D\$16)	
27	curv aer. sur. (1/m)	=\$B\$26/(\$D\$13+\$C\$13)	
28			
29	Surface number	Object	
30	Curvature (1/m)	C	
31	Radius of curv (mm)	0	
32	Thickness (m)	10000000000	
33	Thickness (mm)		
34	Index (aer. sur.)		
35			
36	Power (dioptr.)		
37	Reduced Thickness (m)	0	
38	Power of: (dioptr.)	=C32/C34	
39			
40			
41			

Tables. Powers of Eye Surfaces for ± 6 D lenses

	A	B	C
6	RELAXED		
7	STANDARD EYE		
8	Surface number		Object
9	Curvature (1/m)	0	
10	Radius of curv (mm)	0	
11	Thickness (m)	0	
12	Thickness (mm)	100000000000	
13	Index (after surfl.)	1	
14			
15	Power (diopters)	0	
16	Reduced Thickness (m)	=C11/C13	
17	Power at: (diopters)		
18			
19			
20			
21			
22	RELAXED		
23	EYE REQUIRING ± 6 D CORRECTION		
24	Power at: (diopters)		
25		corners: =(50.872*\$H\$19)/(1-\$H\$19*0.00573/3E\$13)	
26		Ant surface: =(825.5\$E\$15)/(1-\$E\$15*5D\$16)	
27	curv ant surfl (1/m)	=5B\$26/5D\$13.5C\$13)	
28			
29	Surface number	0	
30	Curvature (1/m)	0	
31	Radius of curv (mm)	100000000000	
32	Thickness (m)	1	
33	Thickness (mm)		
34	Index (after surfl.)		
35			
36	Power (diopters)	0	
37	Reduced Thickness (m)	=C32/C34	
38	Power at: (diopters)		
39			
40			
41			

Tables. Powers of Eye Surfaces for $\pm 6D$ lenses

	A	B	C
4.2	ACCOMMODATED		
4.3	STANDARD EYE		
4.4	<i>Surface number</i>	0	
4.5	<i>Curvature (1/m)</i>	0	
4.6	<i>Radius of curv (mm)</i>		
4.7	<i>Thickness (m)</i>		
4.8	<i>Thickness (mm)</i>		
4.9	<i>Index (after surf.)</i>		
5.0		0	
5.1	<i>Power (diopters)</i>		
5.2	<i>Reduced Thickness (m)</i>		$=C47/C49$
5.3	<i>Power of (diopters)</i>		
5.4			
5.5			
5.6			
5.7	ACCOMMODATED		
5.8	EYE REQUIRING $\pm 6D$ CORRECTION		
5.9	<i>Power of (diopters)</i>		
6.0			$=(71.584 \cdot \$H\$55)/(1 \cdot \$H\$55 \cdot 0.0051956/\$E\$13)$
6.1			$=(B60 \cdot \$E\$5)/(1 \cdot \$E\$51 \cdot \$D\$52)$
6.2	<i>curv ant surf (1/m)</i>		$=\$B61/(\$D\$49 \cdot \$C\$49)$
6.3			
6.4	<i>Surface number</i>	0	
6.5	<i>Curvature (1/m)</i>	0	
6.6	<i>Radius of curv (mm)</i>		
6.7	<i>Thickness (m)</i>		
6.8	<i>Thickness (mm)</i>		
6.9	<i>Index (after surf.)</i>		
7.0		1	
7.1	<i>Power (diopters)</i>		
7.2	<i>Reduced Thickness (m)</i>		$=C67/C69$
7.3	<i>Power of (diopters)</i>		
7.4			
7.5			
7.6			

Tables. Powers of Eye Surfaces for $\pm 6D$ lenses

D	E	F	G
6			
7	A. Cornea	P. cornea	A. lens core
8			
9	$=1/0.0077$	$=1/0.0068$	$3 = 1/0.01$
10	$=1000/D9$	$=1000/E9$	$=1000/F9$
11	0.0005	0.0031	0.000546
12	$=1000/D11$	$=1000 \cdot E11$	$=1000 \cdot F11$
13	1.376	1.336	1.386
14			1.406
15	$=(C_{13} \cdot D_{13}) \cdot D9$	$=(D_{13} \cdot E_{13}) \cdot E9$	$=-(E_{13} \cdot F_{13}) \cdot F9$
16	$=D_{11}/D_{13}$	$=E_{11}/E_{13}$	$=F_{11}/F_{13}$
17	Conea:	$=D15+E15-(D15 \cdot E15 \cdot D16)$	$=G11/G13$
18			A. lens core:
19			A. cortex + core
20			equivalent lens
21			cornea + lens
22			
23		Required power of eye = 58.872 D	
24			
25			
26			
27			
28	A. Cornea	P. cornea	A. lens cortex
29			
30	$=S8326/(S8313 \cdot C_{13})$	$=1/0.0068$	$3 = 1/0.01$
31	$=1000/D30$	$=1000/E30$	$=1000/F30$
32	0.0005	0.0031	0.000546
33	$=1000/D32$	$=1000 \cdot E32$	$=1000 \cdot F32$
34	1.376	1.336	1.386
35			1.406
36	$=(C_{34} \cdot D_{34}) \cdot D30$	$=(D_{34} \cdot E_{34}) \cdot E30$	$=-(E_{34} \cdot F_{34}) \cdot F30$
37	$=E_{32}/E_{34}$	$=D32/D34$	$=-(F_{34} \cdot G_{34}) \cdot G30$
38	Conea:	$=D36+E36-(D36 \cdot E36 \cdot D37)$	$=G32/G34$
39			A. lens core:
40			A. cortex + core
41			equivalent lens
			cornea + lens

Tables. Powers of Eye Surfaces for $\pm 6D$ lenses

	0	E	F	G
42				
43	A. Cornea	P. cornea	A. lens cortex	A. lens core
44	1	2	3	4
45	$=10.0077$	$=10.0068$	$=1/0.0053.3$	$=1/0.002655$
46	$=1000/D45$	$=1000/E45$	$=1000/F45$	$=1000/G45$
47	0.0005	0.0027	0.0006725	0.002655
48	$=1000\cdot D47$	$=1000\cdot E47$	$=1000\cdot F47$	$=1000\cdot G47$
49	1.376	1.336	1.386	1.406
50				
51	$=(C49-D49)\cdot D45$	$=(D49-E49)\cdot E45$	$=-(E49-F49)\cdot F45$	$=-(F49-G49)\cdot G45$
52	$=D47/D49$	$=E47/E49$	$=F47/F49$	$=G47/G49$
53				
54				
55				
56				
57				
58				
59				
60				
61				
62				
63	A. Cornea	P. cornea	A. lens cortex	A. lens core
64	1	2	3	4
65	$=\$B\62	$=10.0068$	$=1/0.0053.3$	$=1/0.002655$
66	$=1000/D65$	$=1000/E65$	$=1000/F65$	$=1000/G65$
67	0.0005	0.0027	0.0006725	0.002655
68	$=1000\cdot D67$	$=1000\cdot E67$	$=1000\cdot F67$	$=1000\cdot G67$
69	1.376	1.336	1.386	1.406
70				
71	$=(C69-D69)\cdot D65$	$=(D69-E69)\cdot E65$	$=-(E69-F69)\cdot F65$	$=-(F69-G69)\cdot G65$
72	$=D67/D69$	$=E67/E69$	$=F67/F69$	$=G67/G69$
73				
74				
75				
76				

Tables. Powers of Eye Surfaces for ± 6D lenses

H	P. lens core	P. lens cortex
6		6
7		= 1/-0.006
8		= 1/0.006
9	= -1/0.00576	
10	= 1000/H9	= 1000/19
11	0.000635	0.0172
12	= 1000/H11	= 1000/11
13	1.386	1.326
14		
15	= (G13+H13)/H9	= (H13+H13)/19
16	= H11/H13	= 111/113
17	= G15+H15·(G15/H15·G16)	
18	= F15+H17·F15·H17·(F11+G11/1.4)/F13	
19	= H18+H15·H18·H15·(H11+G11/1.4)/H13	
20	= E17·H19·E17·H19·(0.00573)/E13	
21		
22		
23		
24		
25		
26		
27		
28	P. lens core	P. lens cortex
29	5	6
30	= 1/0.00576	= 1/-0.006
31	= 1000/H30	= 1000/130
32	0.000635	0.0172
33	= 1000/H32	= 1000/132
34	1.386	1.326
35		
36	= (G34+H34)/H30	= (H34+H34)/130
37	= H32/H34	= 132/134
38	= G36+H36·(G36·H36·G37)	
39	= F36+H38·F36·H38·(F32·G32/1.4)/F34	
40	= H39+H36·H39·H36·(H32+G32/1.4)/H34	
41	= E38+H40·E38·H40·(0.00573)/E34	

Tables. Powers of Eye Surfaces for $\pm 6D$ lenses

	H		I
4.2			
4.3	P. lens core		
4.4	5		
4.5	$= 1/0.002655$		
4.6	$= 1/000/H45$		
4.7	0.0006725		
4.8	$= 1/000/H47$		
4.9	1.386		
5.0			
5.1	$-(G49+H49)/H45$		
5.2	$= H47/H49$		
5.3	$= G51+H51-(G51/H51+G52)$		
5.4	$= F51+H53-F51+H53 \cdot (F47+G47/1.41)/F49$		
5.5	$= H54+151+H54+151 \cdot (H47+G47/1.41)/H49$		
5.6	$= E53+H55-E53+H55 \cdot (0.0051956)/E49$		
5.7			
5.8			
5.9			
6.0			
6.1			
6.2			
6.3	P. lens core		
6.4	5		
6.5	$= -1/0.002655$		
6.6	$= 1/000/H65$		
6.7	0.0006725		
6.8	$= 1/000/H67$		
6.9	1.386		
7.0			
7.1	$-(G69+H69)/H65$		
7.2	$= H67/H69$		
7.3	$= G71+H71-(G71/H71+G72)$		
7.4	$= F71+H73-F71+H73 \cdot (F67+G67/1.41)/F69$		
7.5	$= H74+171+H74+171 \cdot (H67+G67/1.41)/H69$		
7.6	$= E73+H75-E73+H75 \cdot (0.0051956)/E69$		

Table 3. Relaxed Eye.

Field points are (x angle, y angle) in degrees; chief ray is (x, y) location on retina in mm; rms spot size is in microns.

Field point	Standard eye	Eye & -6 D lens	Eye, lens, and wedge
(0,0)			
chief ray	0,0	0,0	0,0
rms spot size	0.11	1.46	1.46
(0,60)			
chief ray	0,12.01	0, 10.45	0, 9.48
rms spot size	66.7	105.0	203.9
(40,40)			
chief ray	7.88,7.98	6.97, 6.97	6.13, 6.13
rms spot size	57.1	80.4	196.3
(75,0)			
chief ray	12.13,0	10.75, 0	9.95, 0
rms spot size	86.2	88.7	217.8

Table 4. Accommodated Eye.

Field points are (x angle, y angle) in degrees; chief ray is (x, y) location on retina in mm; rms spot size is in microns.

Field point	Standard eye	+ 6 D lens	+6 D lens, and wedges	Thin +6 D lens, wedges
(0,0)	1			
chief ray	0,0	0,0	0,0	0, 0
rms spot size	3.6	4.6	4.6	4.6
(0,40)				
chief ray	0,9.69	0, 11.19	0, 9.31	0, 9.11
rms spot size	135.3	134.0	163.4	165.2
(30,30)				
chief ray	6.77,6.77	7.80, 7.80	6.48, 6.48	6.33, 6.33
rms spot size	131.9	138.6	163.5	166.3

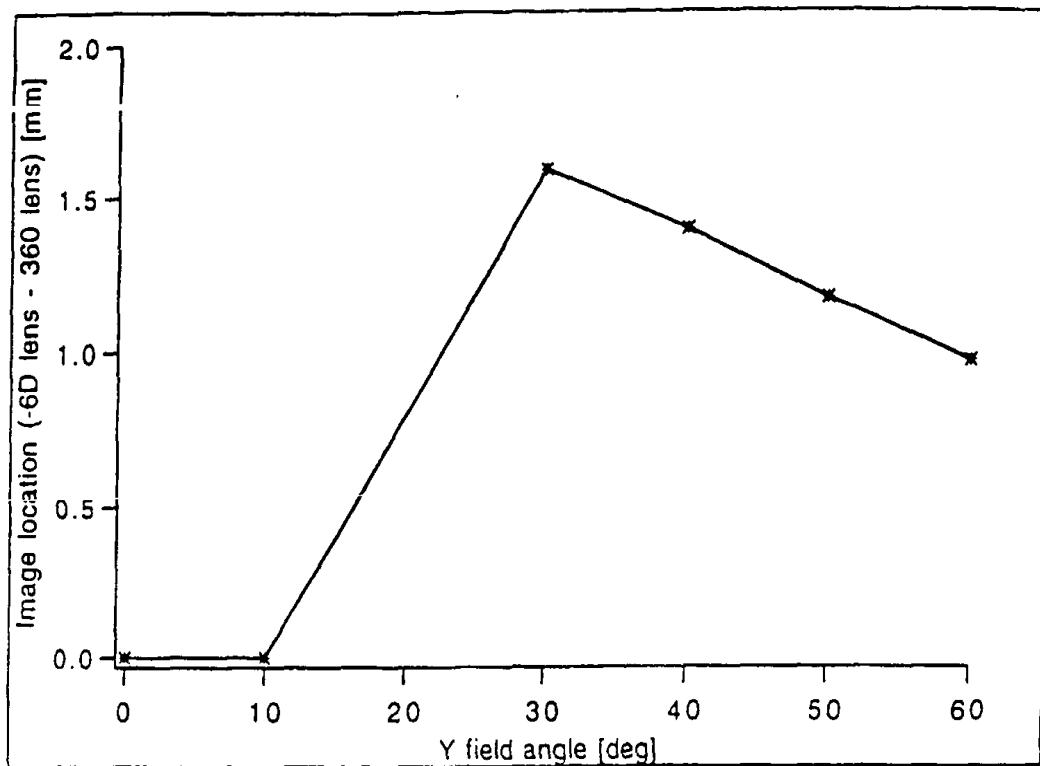


Figure 1. Change in image location for 360 lens on -6 D corrective lens, relaxed eye, vertical object

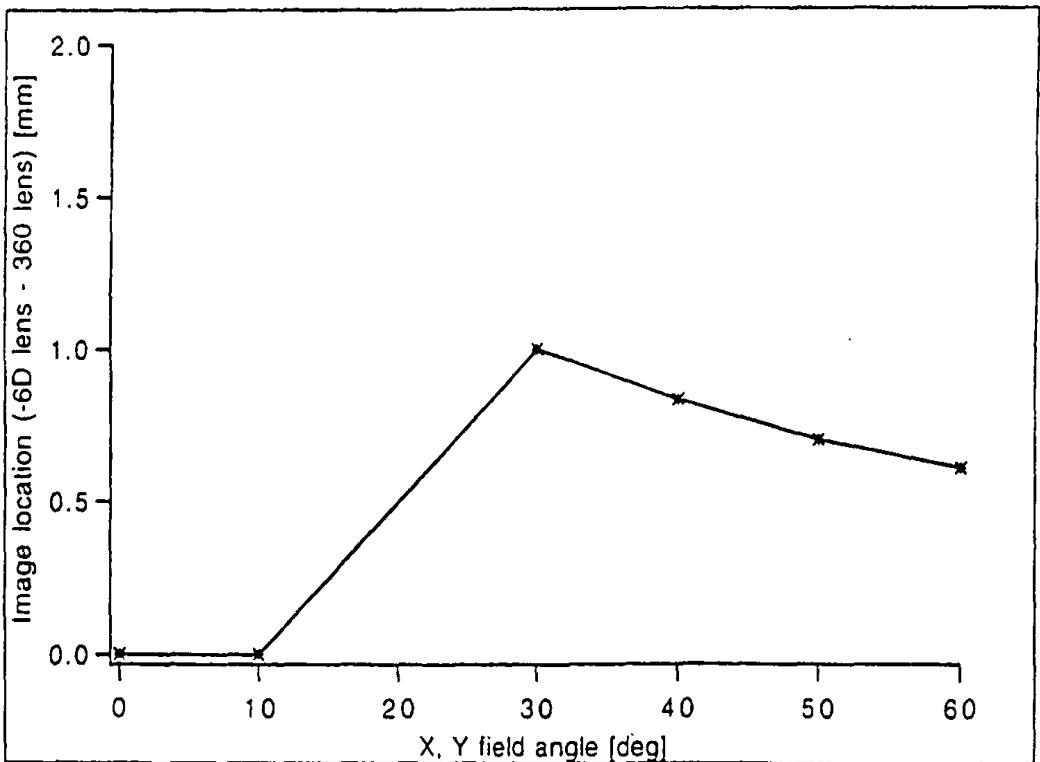


Figure 2. Change in image location for 360 lens on -6 D corrective lens, relaxed eye, 45 ° object

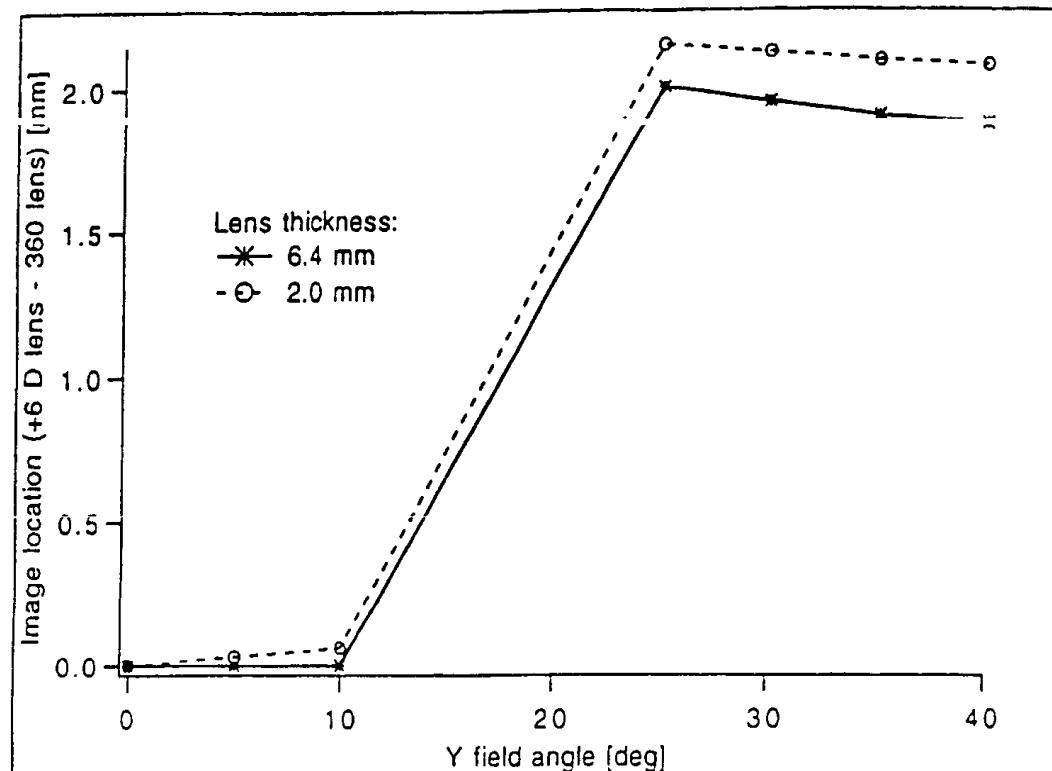


Figure 3. Change in image location for 360 lens on +6 D corrective lens, accommodated eye, vertical object

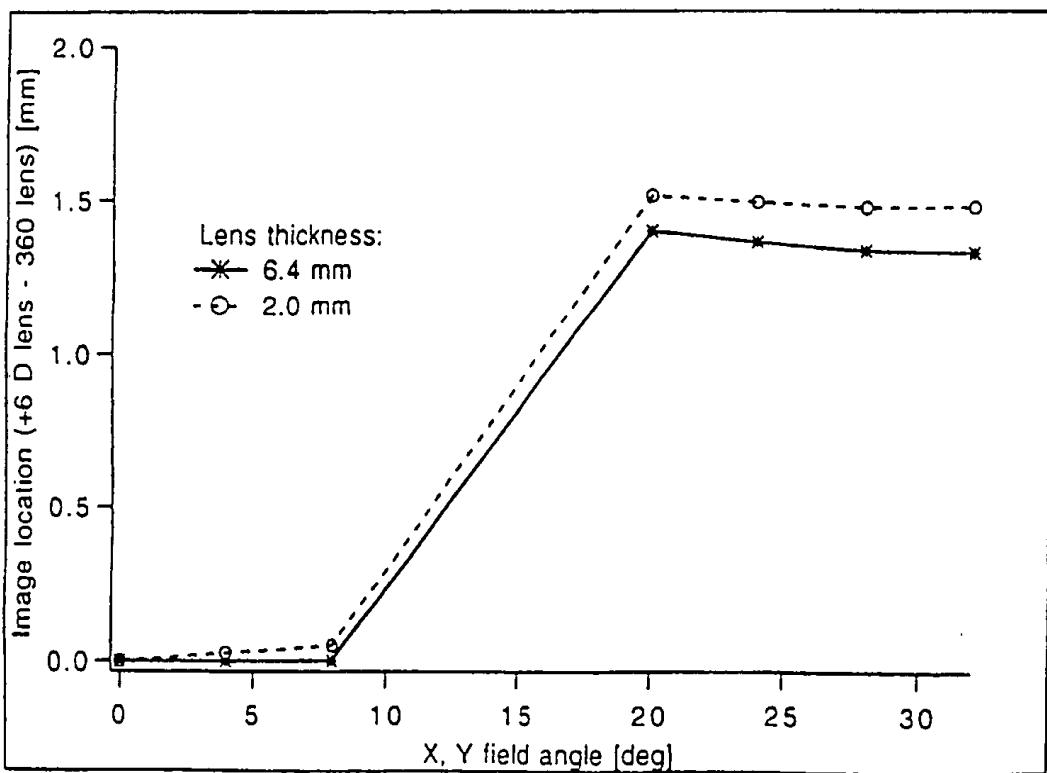
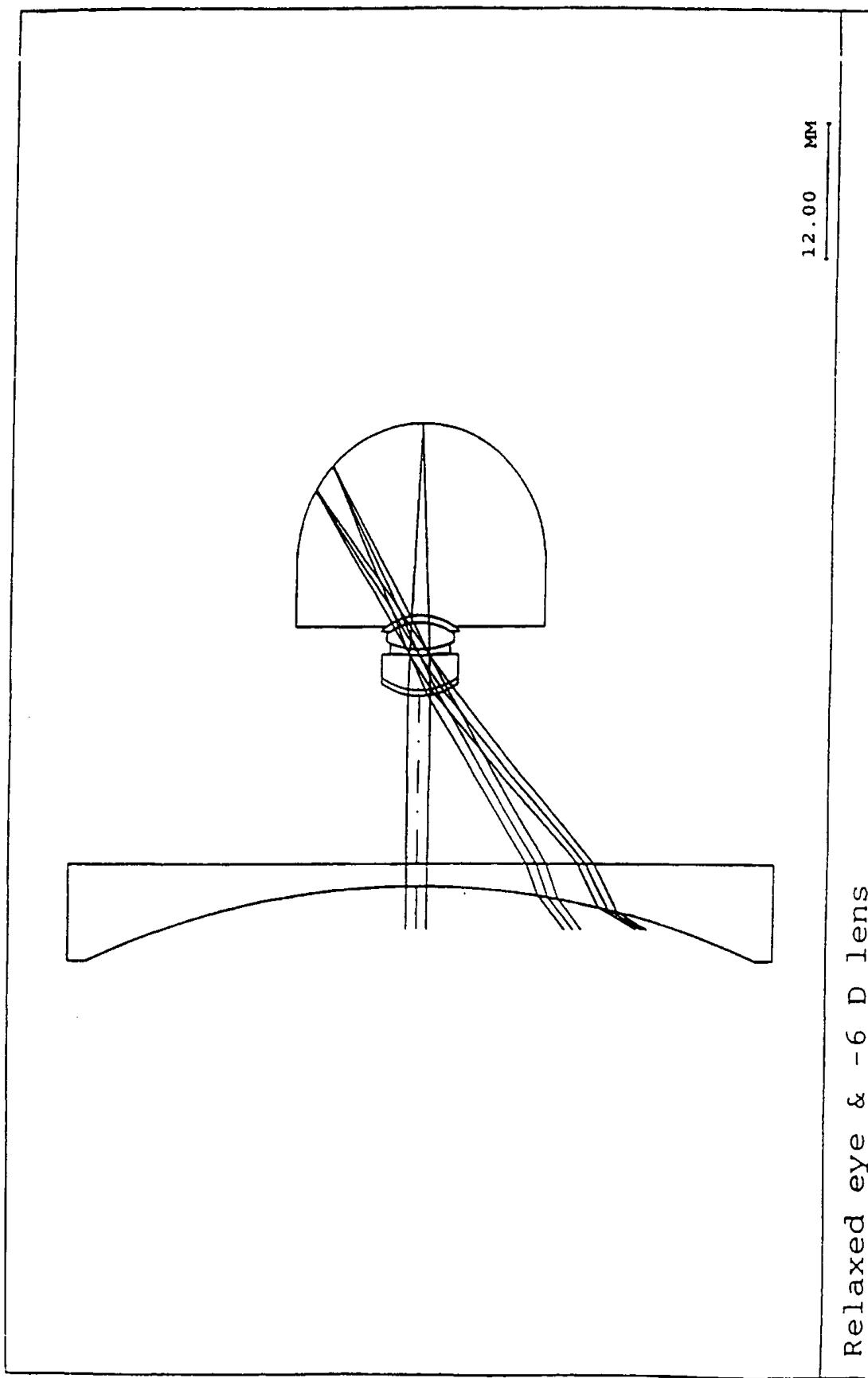


Figure 4. Change in image location for 360 lens on +6 D corrective lens, accommodated eye, 45 ° object



Relaxed eye & -6 D lens

```

Relaxed eye & -6 D lens
  RDY      THI      RMD      GLA      CCY      THC      GLC
  > OBJ:  INFINITY  INFINITY  AIR      'CR39.
  1:      -83.08330  2.000000  'CR39.
  2:      INFINITY   15.000000  AIR      'CORNEA'
  3:      6.91815   0.500000  'CORNEA'
  4:      6.800000  3.100000  'AQUEOUS.
  STO:   10.000000  0.546000  'CORTEX.
  ASP:
  K : 0.000000  KC : 100
  IC : YES      CUF: 0.000000
  A : -406812E-02 B : 0.000000E+00
  AC : 0          BC : 100
  EPD: 2.000000
  DIM: MM
  WL: 587.60
  REF: 1
  WTW: 1
  XAN: 0.000000
  YAN: 0.000000
  VUX: 0.000000
  VLX: 0.000000
  VUY: 0.000000
  VLY: 0.000000
  CCF: 100
  CC : 0.000000E+00
  CC : 100
  D : 0.000000E+00
  DC : 100
  DC : 100
  'CORE.
  'CORTEX.
  'VITREOUS.
  AIR
  SPECIFICATION DATA
  EPD: 2.000000
  DIM: MM
  WL: 587.60
  REF: 1
  WTW: 1
  XAN: 0.000000
  YAN: 0.000000
  VUX: 0.000000
  VLX: 0.000000
  VUY: 0.000000
  VLY: 0.000000
  0.000000
  0.000000
  0.04053
  0.04053
  0.16470
  0.15629
  60.00000
  0.10784
  0.10784
  0.50029
  0.50112
  APERTURE DATA/EDGE DEFINITIONS
  CA      32.500000
  CIR S1  32.500000
  CIR S2  32.500000

```

Relaxed eye & -6 D lens

PRIVATE CATALOG	
PWL	587.60
'CORNEA'	1.376000
'AQUEOUS'	1.336000
'CORTEX'	1.386000
'CORE'	1.406000
'VITREOUS'	1.336000
'CR39'	1.498500

REFRACTIVE INDICES

GLASS CODE	587.60
'CR39'	1.498500
'CORNEA'	1.376000
'AQUEOUS'	1.336000
'CORTEX'	1.386000
'CORE'	1.406000
'VITREOUS'	1.336000

No solves defined in system

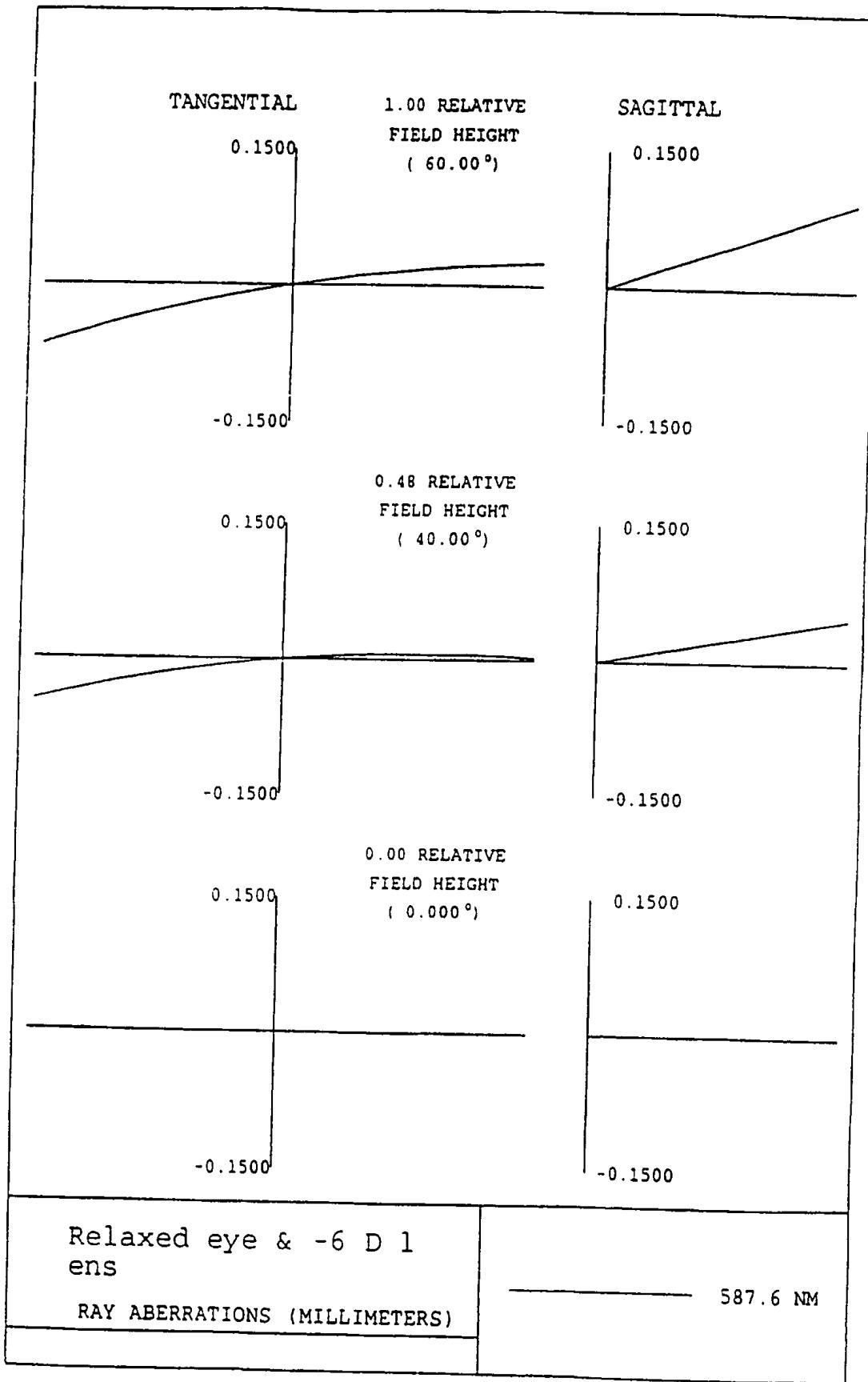
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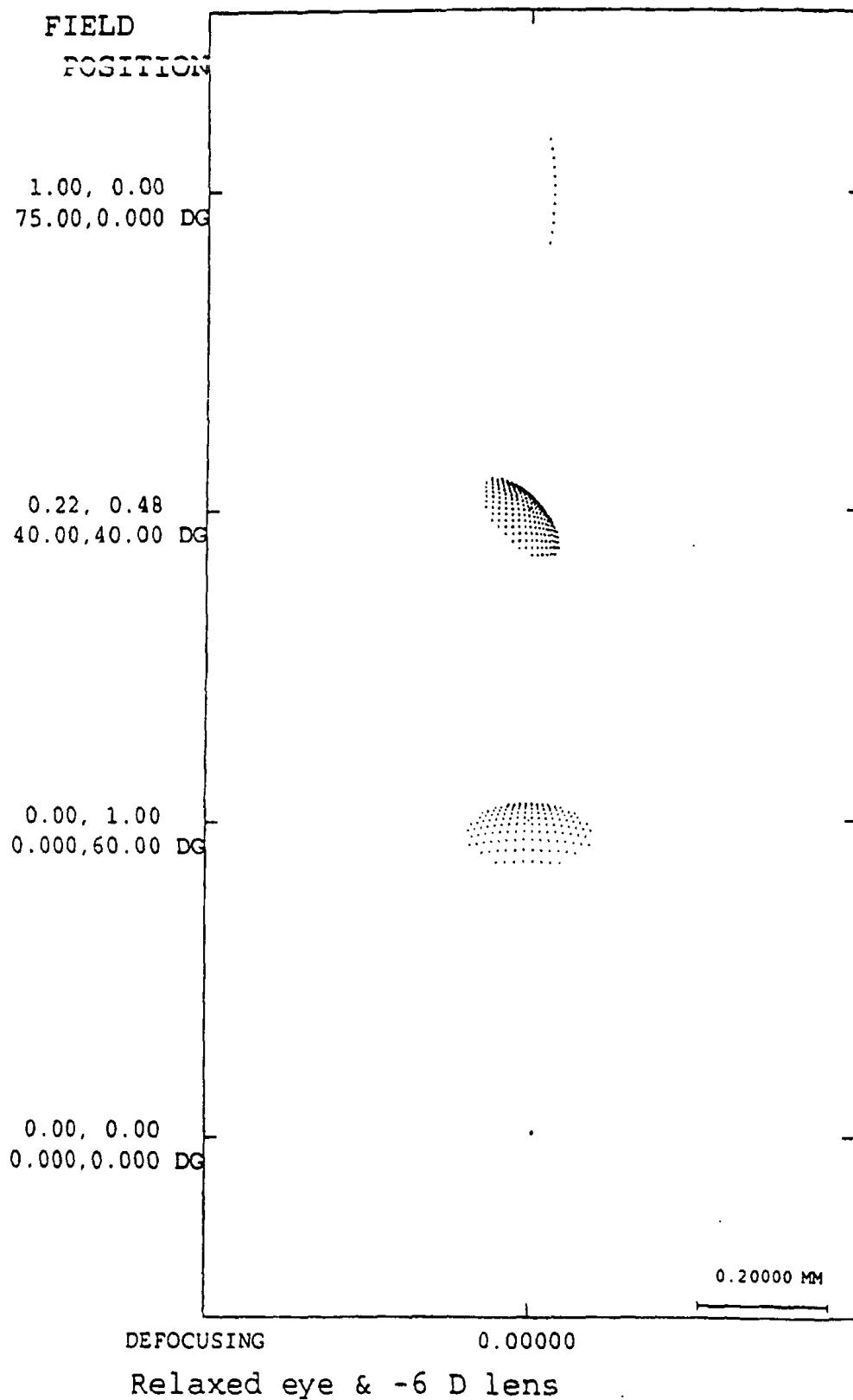
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BFL	17.1644
FFL	1.8600
FNO	7.7594
IMG DIS	17.1823
OAL	24.2000
PARAXIAL IMAGE	
HT	26.8795
ANG	60.0000
ENTRANCE PUPIL	
DIA	2.0000
THI	17.4045
EXIT PUPIL	
DIA	1.9967
THI	-3.5346

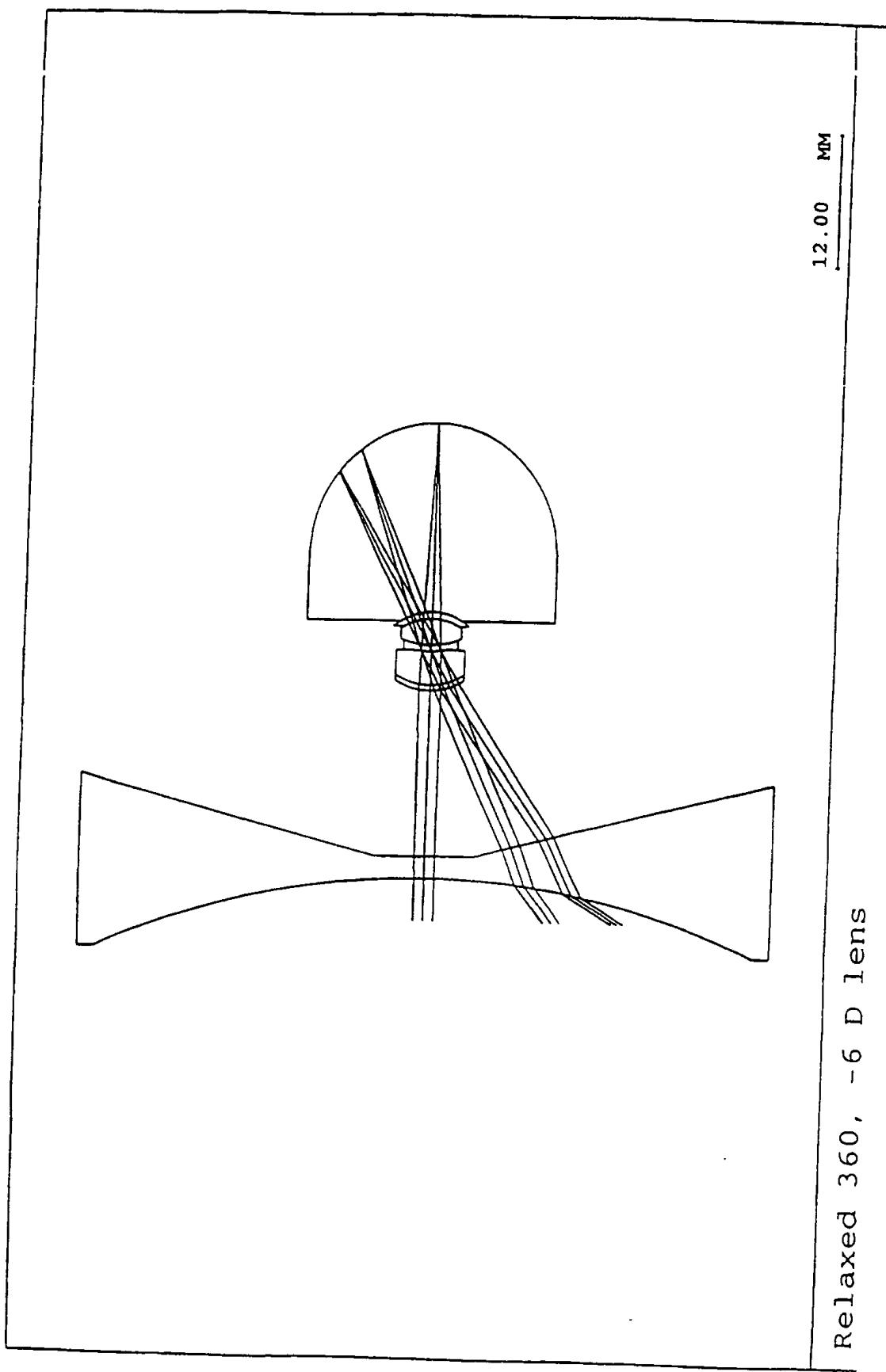
Relaxed eye & -6 D lens

Third order aberrations

Relaxed eye & -6 D lens		Position 1, Wavelength = 587.6 NM		Position 2, Wavelength = 587.6 NM		Position 3, Wavelength = 587.6 NM		Position 4, Wavelength = 587.6 NM	
	SA	TCO	TAS	SAS	PTB	DST	AX	LAT	PTZ
1	0.000003	-0.001568	0.366173	0.184195	0.093206	-32.059219	0.000000	0.000000	0.004004
2	0.000001	0.000727	0.187897	0.062632	0.000000	16.192346	0.000000	0.000000	0.000000
3	-0.007940	-0.123827	-1.563166	-1.134026	-0.919455	-5.895193	0.000000	0.000000	-0.039498
4	0.000415	0.007361	0.118007	0.088993	0.074487	0.526143	0.000000	0.000000	0.003200
SRO	-0.000033	-0.002126	-0.109177	-0.078297	-0.062857	-1.705588	0.000000	0.000000	-0.002700
5	0.011117	0.000000	0.000000	0.000000	0.000000	0.000000	ASSPHERIC CONTRIBUTIONS		
6	-0.000043	-0.002140	-0.066110	-0.042170	-0.030200	-0.707478	0.000000	0.000000	-0.001297
7	-0.001077	0.010608	-0.076322	-0.053092	-0.041477	0.174392	0.000000	0.000000	-0.001782
8	-0.002445	0.021015	-0.164981	-0.124834	-0.104761	0.357711	0.000000	0.000000	-0.004500
SUM	0.000000	-0.089950	-1.307677	-1.096597	-0.991057	-23.116886	0.000000	0.000000	-0.042574







Relaxed 360, -6 D lens

Relaxed 360, -6 D lens
 RDY lens
 > OBJ: RDY THI RMD GLA CCY THC GLC
 1: INFINITY INFINITY AIR 100 100
 2: -93.08330 2.000000 'CR39' 100 100
 INFINITY 15.000000 AIR 100 100

UDS:

IC : YES

UCO/UCC

C1 : 1.3727E+01 C2 : 6.5000E+01 C3 : 1.0000E+01
 C1 : 100 C2 : 100 C3 : 100
 C4 : 1.0000E+01
 C4 : 100

3: 6.91815 0.500000 'CORNEA'
 4: 6.80000 3.100000 'AQUEOUS'
 STO: 10.00000 0.546000 'Cortex'
 ASP:
 K : 0.000000 KC : 100
 IC : YES CUF : 0.000000 CCF : 100
 A : -4.06812E-02 B : 0.000000E+00 C : 0.000000E+00 D : 0.000000E+00
 AC : 0 BC : 100 CC : 100 DC : 100
 6: 7.91100 2.419000 'CORE'
 7: -5.76000 0.635000 'Cortex'
 8: -6.00000 17.182294 'VITREOUS'
 IMG: -12.20000 0.000000 AIR 100 100

SPECIFICATION DATA

EPO

2.00000

DIM

MM

WL

587.60

REF

1

WTW 1
 XAN 0.00000 0.00000 0.00000
 YAN 0.00000 40.00000 60.00000
 VUX 0.00000 0.22148 0.20733
 VLX 0.00000 0.22148 0.20733
 VUY 0.00000 0.12861 0.38966
 VLY 0.00000 0.12120 0.39135

Relaxed 360, -6 D lens

APERTURE DATA/EDGE DEFINITIONS

CA	CIR S1	32.500000
CIR S2		32.500000

PRIVATE CATALOG

PWL	587.60
'CORNEA'	1.376000
'AQUEOUS'	1.336000
'Cortex'	1.386000
'CORE'	1.406000
'VITREOUS'	1.336000
'CR39'	1.498500

REFRACTIVE INDICES

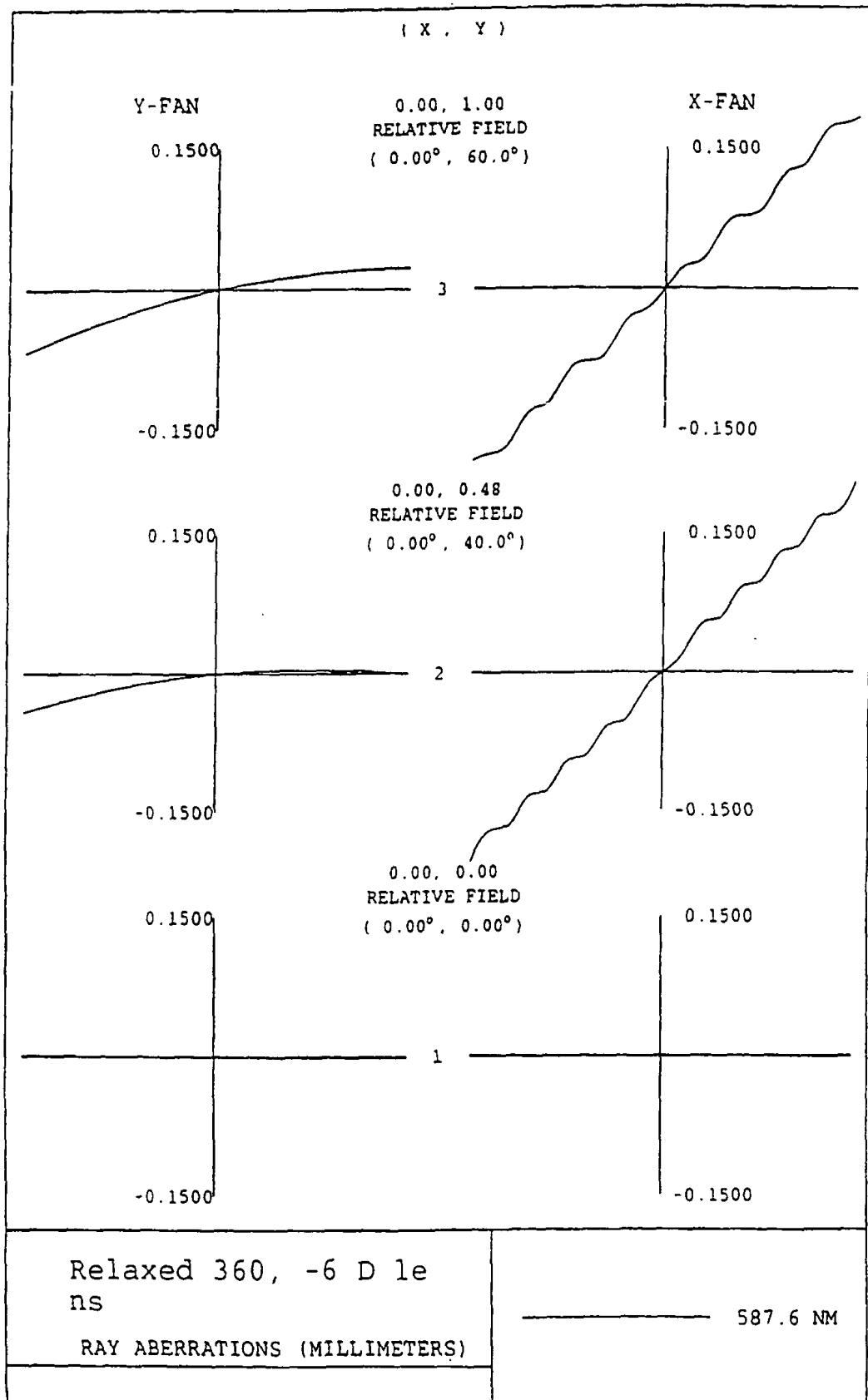
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'CORNEA'	1.376000
'AQUEOUS'	1.336000
'Cortex'	1.386000
'CORE'	1.406000
'VITREOUS'	1.336000

INFINITE CONJUGATES

EFL	20.7312
BFL	17.1644
FFL	1.8600
FNO	7.7594
IMG DIS	17.1823
OAL	24.2000
PARAXIAL IMAGE	
BT	26.8795
ANG	60.0000
ENTRANCE PUPIL	
DIA	2.0000
THI	17.4045
EXIT PUPIL	
DIA	1.9967
THI	-3.5346

Relaxed 360, -6 D lens

Relaxed 360° -> 0° lens		Position 1		Wavelength = 587.6 nm		587.6 nm		587.6 nm		587.6 nm	
SA	TCO	TAS	SAS	PTB	SAS	PTB	SAS	PTB	SAS	PTB	
1	0.000003	-0.001568	0.366173	0.184195	0.093206	-32.059219	0.000000	0.000000	0.000000	0.000000	PTZ
2	0.000001	0.000727	0.187897	0.062632	0.000000	16.192346	0.000000	0.000000	0.000000	0.000000	
3	-0.0007940	-0.123827	-1.563166	-1.134026	-0.919455	-5.895193	0.000000	0.000000	0.000000	-0.039498	
4	0.000415	0.007361	0.118007	0.088993	0.074487	0.526143	0.000000	0.000000	0.000000	0.003200	
STO	-0.000033	-0.002126	-0.109177	-0.078297	-0.062857	-1.705588	0.000000	0.000000	0.000000	-0.002700	
	0.011117	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	ASPERIC CONTRIBUTIONS
6	-0.000043	-0.002140	-0.066110	-0.042170	-0.030200	-0.707478	0.000000	0.000000	0.000000	-0.001297	
7	-0.001077	0.010608	-0.076322	-0.053092	-0.041477	0.174392	0.000000	0.000000	0.000000	-0.001782	
8	-0.002445	0.021015	-0.164981	-0.124834	-0.104761	0.357711	0.000000	0.000000	0.000000	-0.004500	
SUM	0.000000	-0.089950	-1.3071677	-1.096597	-0.991057	-23.116886	0.000000	0.000000	0.000000	-0.042574	

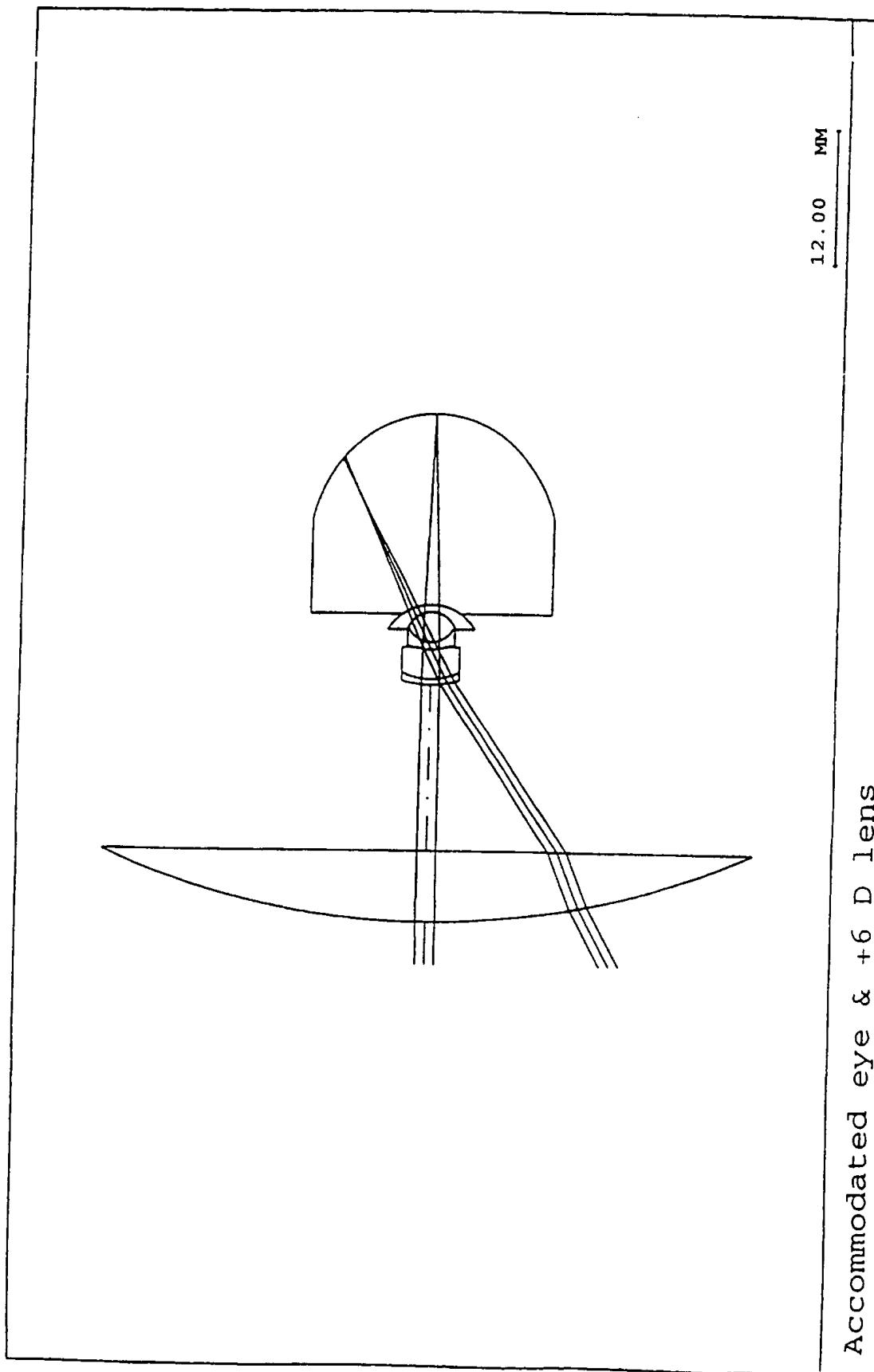


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0.000, 0.000 DG

DEFOCUSING

0.00000

Relaxed 360, -6 D lens



Accommodated eye & +6 D lens

Accommodated eye & +6 D lens		RDY	THI	RMD	AIR	GLA	CCY	THC	GLC
> OBJ :	INFINITY	400.000000			'CR39'			100	100
1:	83.08330	6.400000			AIR			100	100
2:	INFINITY	15.000000			'CORNEA'			100	100
3:	11.07116	0.500000			'AQUEOUS'		0	100	100
4:	6.80000	2.700000			'Cortex'		100	100	100
STO:	5.33000	0.672500							
ASP:									
K :	0.000000	KC :	100						
IC :	YES	CUF :	0.000000						
A :	-5922348E-02	B :	0.000000E+00						
AC :	0	BC :	100						
6:	2.65500	2.655000			'CORE'		100	100	
7:	-2.65500	0.672500			'Cortex'		100	100	
8:	-5.330000	17.182294			'VITREOUS'		100	100	
IMG:	-12.20000	0.000000			AIR		100	100	
SPECIFICATION DATA									
EPD	2.00000								
DIM	MM								
WL	587.60								
REF	1								
WTW	1								
XAN	0.00000	0.00000					0.00000	0.00000	
YAN	0.00000	30.00000					40.00000	40.00000	
VIY	0.00000	0.00000					0.00000	0.00000	
VLY	0.00000	0.00000					0.00000	0.00000	
APERTURE DATA/EDGE DEFINITIONS									
CA									
CIR S1		32.500000							
CIR S2		32.500000							
PRIVATE CATALOG									
PWL	587.60								
'CORNEA'	1.376000								
'AQUEOUS'	1.336000								
'Cortex'	1.386000								
'CORE'	1.406000								
'VITREOUS'	1.336000								
'CR39'	1.498500								

Accommodated eye & +6 D lens

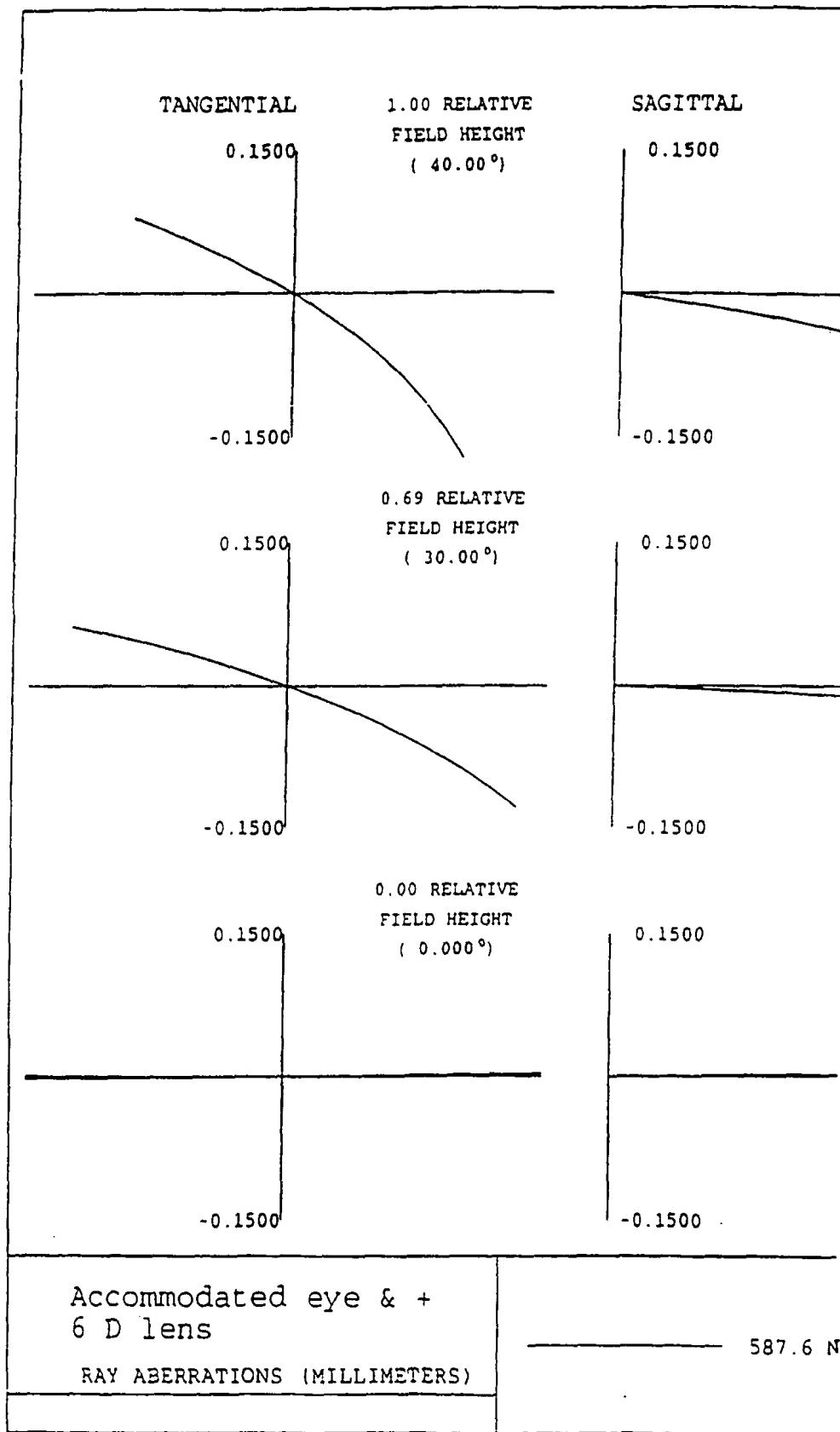
REFRACTIVE INDICES	
GLASS CODE	587.60
'CR39'	1.498500
'CORNEA'	1.376000
'AQUEOUS'	1.336000
'CORTEX'	1.386000
'CORE'	1.406000
'VITREOUS'	1.336000

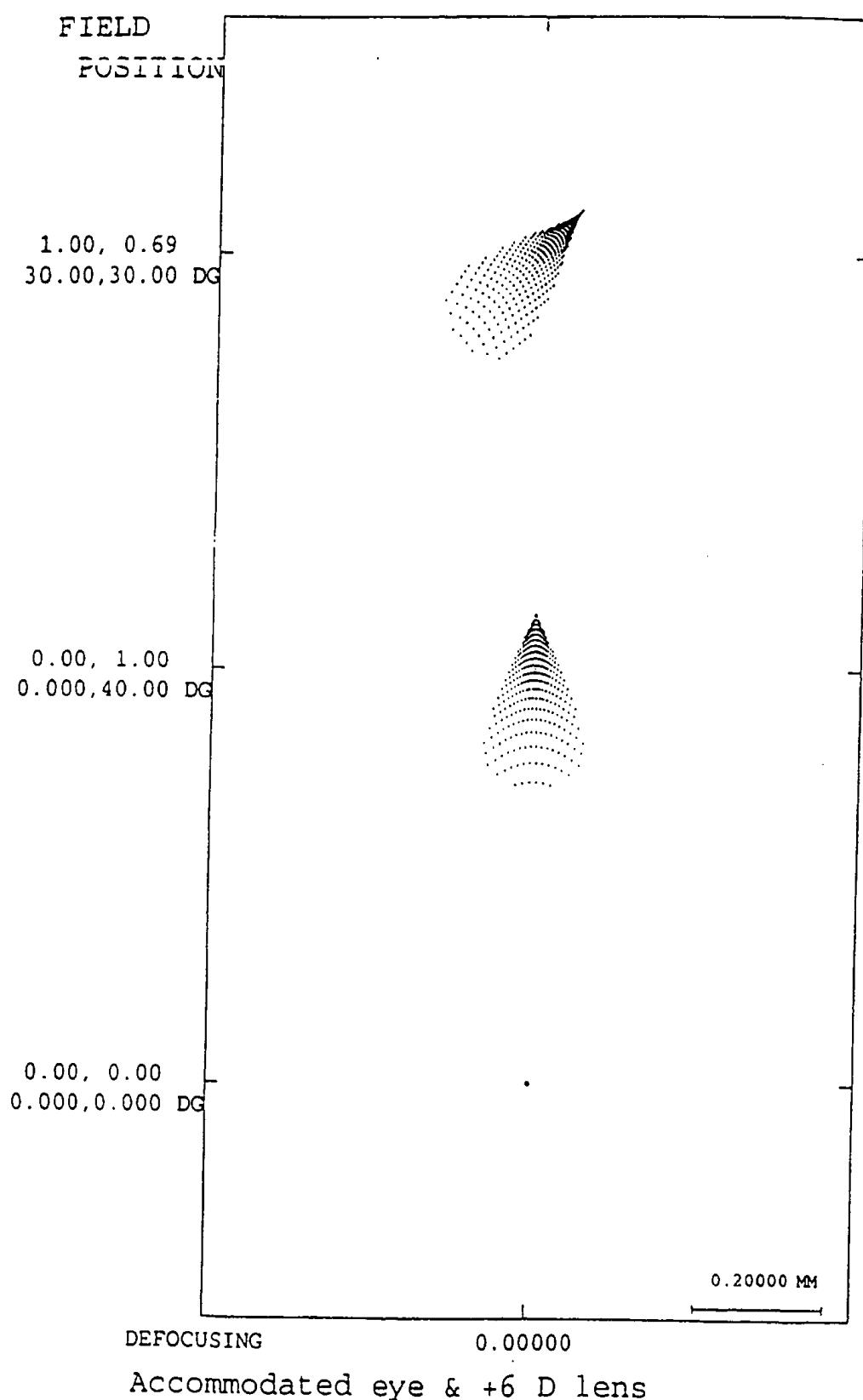
No solves defined in system

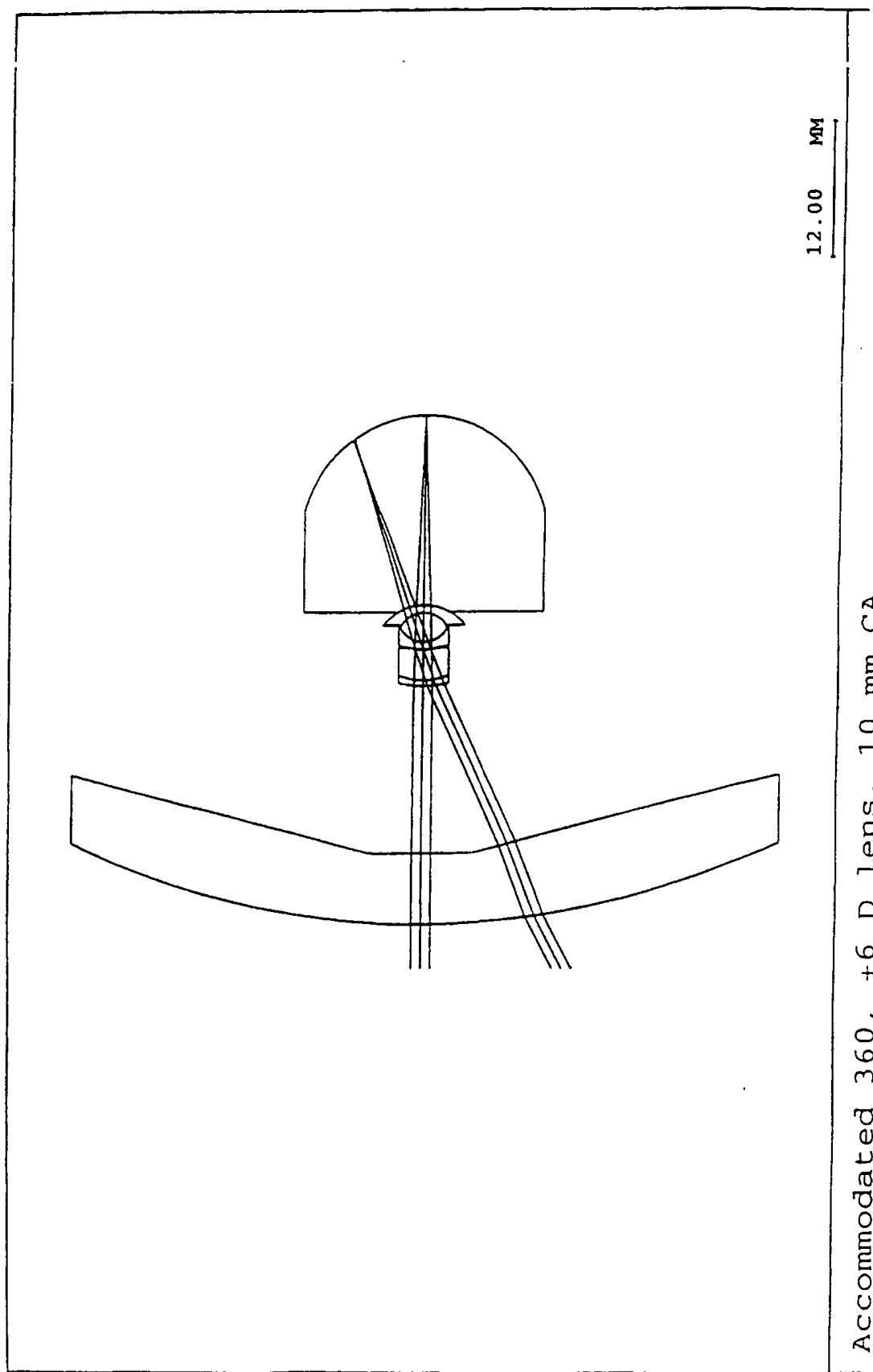
INFINITE CONJUGATES	
EFL	23.7860
BFL	16.2232
FFL	4.1771
FNO	8.9020
AT USED CONJUGATES	
RED	0.0440
FNO	9.3635
OBJ DIS	400.0000
TT	445.7823
IMG DIS	17.1823
OAL	28.6000
PARAXIAL IMAGE	
HT	16.0022
THI	17.2710
ANG	40.0000
ENTRANCE PUPIL	
DIA	2.0000
THI	25.1299
EXIT PUPIL	
DIA	1.6994
THI	-3.9881

Accommodated eye & +6 D lens

Third order aberrations		Accommodated eye & +6 D lens		Position 1, Wavelength = 587.6 NM		Position 1, Wavelength = 587.6 NM		Position 1, Wavelength = 587.6 NM		Position 1, Wavelength = 587.6 NM	
SA	TCO	TAS	TAS	SAS	PTB	DST	AX	LAT	PTZ	AX	LAT
1	-0.00006	-0.000823	-0.063232	-0.039328	-0.027375	-1.713917	0.00000	0.00000	-0.004004	0.00000	0.00000
2	0.00000	0.000154	-0.045984	-0.015328	0.000000	4.577003	0.00000	0.00000	0.000000	0.00000	0.00000
3	-0.000672	-0.020061	-0.368252	-0.235249	-0.168748	-2.319481	0.00000	0.00000	-0.024682	0.00000	0.00000
4	0.000293	0.003936	0.039532	0.027762	0.021877	0.124517	0.00000	0.00000	0.003200	0.00000	0.00000
STO	-0.000656	-0.011904	-0.106612	-0.058628	-0.034637	-0.354487	0.00000	0.00000	-0.005066	0.00000	0.00000
	0.009494	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
6	-0.002635	-0.027716	-0.123611	-0.058823	-0.026429	-0.206256	0.000000	0.000000	-0.003866	0.000000	0.000000
7	-0.003997	-0.007766	-0.031459	-0.028105	-0.026429	-0.018202	0.000000	0.000000	-0.003866	0.000000	0.000000
8	-0.001820	0.006104	-0.041461	-0.036911	-0.034637	0.041271	0.000000	0.000000	-0.005066	0.000000	0.000000
SUM	0.000000	-0.058076	-0.741078	-0.444611	-0.296378	0.110448	0.000000	0.000000	-0.043349	0.000000	0.000000







Accommodated 360, +6 D lens, 10 mm CA

```

Accommodated 360, +6 D lens, 10 mm CA
  RDY   TH1   RMD   AIR   GLA   CCY   THC   GLC .
OBJ: INFINITY 400.000000 AIR   'CR39' .
1:     83.08330 6.400000 AIR   .
2: INFINITY 15.000000 AIR   .
UDS:
  IC : YES
  UCO/UCC
  C1 : 1.3727E+01 C2 : 6.5000E+01 C3 : 1.0000E+01
  C1 : 100          C2 : 100          C3 : 100
  C4 : 1.0000E+01
  C4 : 100          C4 : 100          C4 : 100

  3: 11.07116 0.500000 'CORNEA' .
  4: 6.80000 2.700000 'AQUEOUS' .
  STO: 5.33000 0.672500 'CORTEX' .
  ASP:
  K : 0.000000 KC : 100
  IC : YES CUF: 0.000000 CCF: 100
  A : -5.92148E-02 B : 0.000000E+00 C : 0.000000E+00 D : 0.000000E+00
  AC : 0 BC : 100 CC : 100 DC : 100
  6: 2.65500 2.655000 'CORE' .
  7: -2.65500 0.672500 'CORTEX' .
  8: -5.33000 17.182294 'VITREOUS' .
  > IMG: -12.20000 0.000000 AIR

```

SPECIFICATION DATA

EPD	2.000000						
DIM	MM						
WL	587.60						
REF	1						
WTW	1						
XAN	0.00000	0.00000					
YAN	0.00000	30.00000	40.00000				
VUX	0.00000	0.00000	0.00000				
VLX	0.00000	0.00000	0.00000				
VUY	0.00000	0.00000	0.00000				
VLY	0.00000	0.00000	0.00000				

Accommodated 360, +6 D lens, 10 mm CA

APERTURE DATA/EDGE DEFINITIONS

CA	CIR S1	32.500000
CIR S2		32.500000

PRIVATE CATALOG

PWL	587.60
'CORNEA'	1.376000
'AQUEOUS'	1.336000
'CORTEX'	1.386000
'CORE'	1.406000
'VITREOUS'	1.336000
'CR39'	1.498500

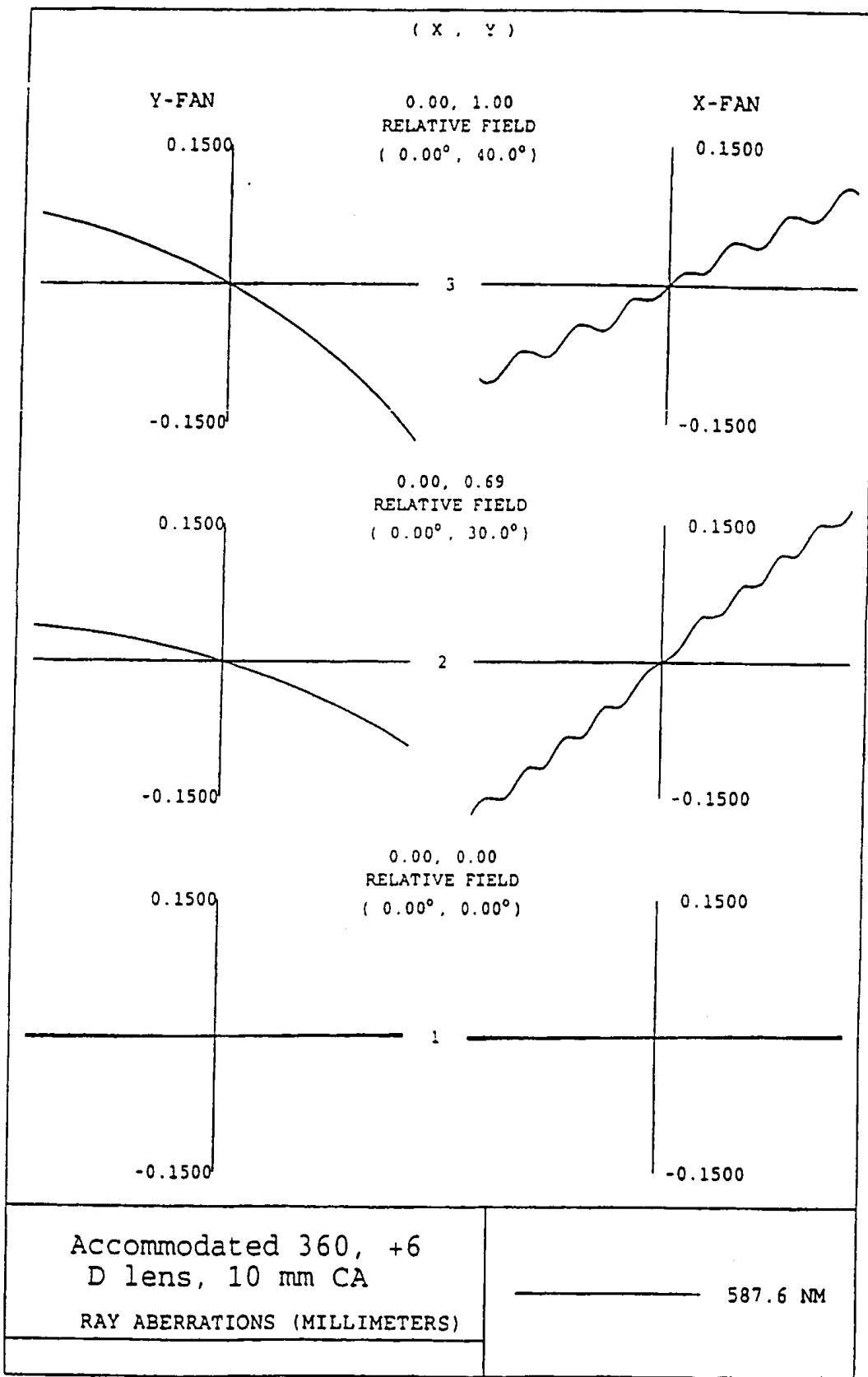
REFRACTIVE INDICES

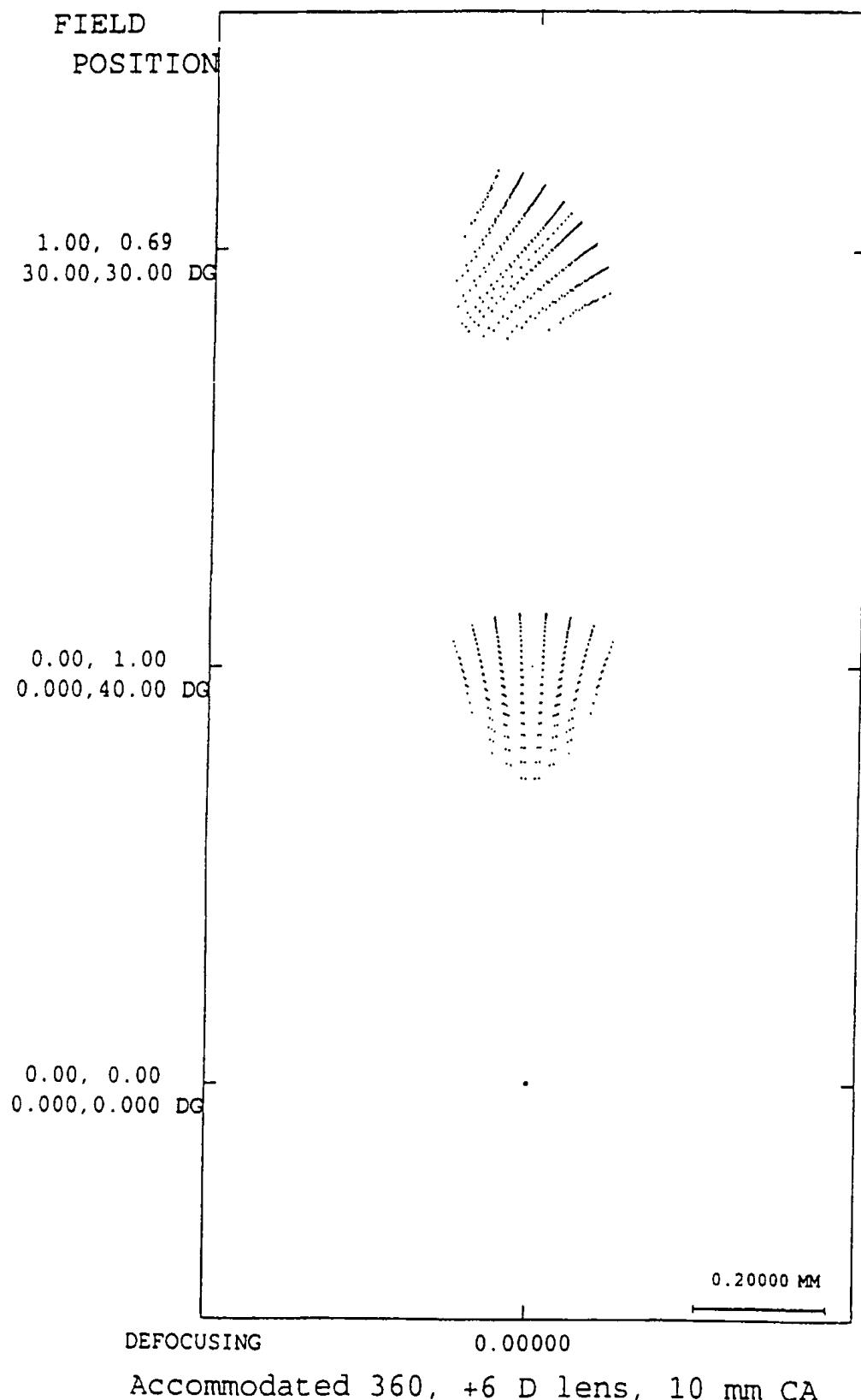
GLASS CODE	587.60
'CR39'	1.498500
'CORNEA'	1.376000
'AQUEOUS'	1.336000
'CORTEX'	1.386000
'CORE'	1.406000
'VITREOUS'	1.336000

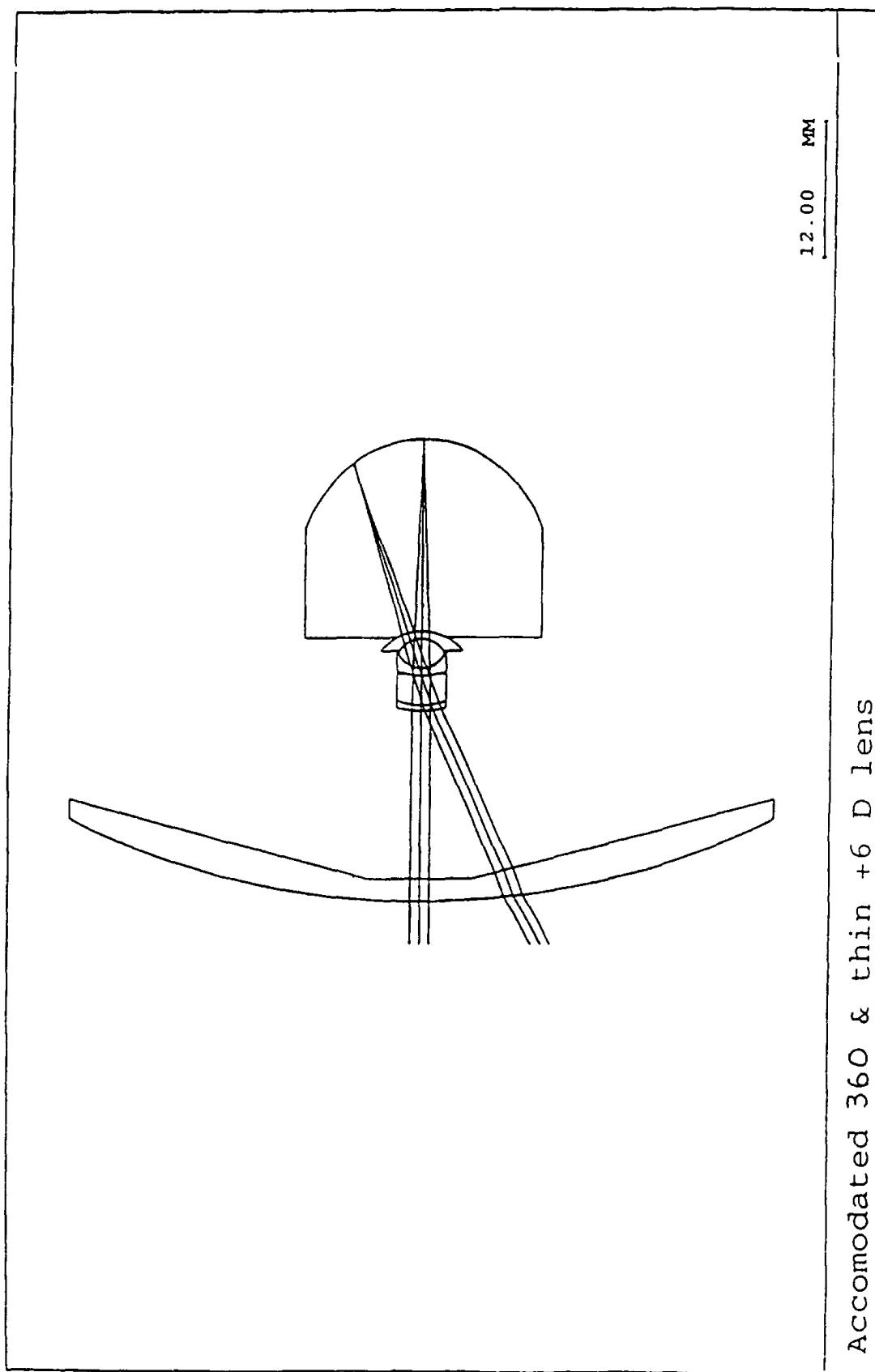
Accommodated 360 & thin +6 D lens

INFINITE CONJUGATES		
EFL	23	.3501
BFL	16	.2528
FFL	1	.1567
FNO	8	.7388
AT USED CONJUGATES		
RED	0	.0436
FNO	9	.1781
OBJ DIS	400	.0000
TT	441	.3823
IMG DIS	17	.1823
OAL	24	.2000
PARAXIAL IMAGE		
HT	15	.2490
THI	17	.2701
ANG	40	.0000
ENTRANCE PUPIL		
DIA	2	.0000
THI	21	.3190
EXIT PUPIL		
DIA	1	.7337
THI	-3	.9881

Third order aberrations This is a non-rotationally symmetric system first order properties and third order quantities derived from them are probably inadequate in describing system characteristics and performance.







Accommodated 360 & thin +6 D lens

Accommodated 360 & thin +6 D lens		RDY		THI		RMD		GLA		CCY		THC		GLC			
OBJ:	INFINITY	1:	83.08330	2:	INFINITY		400.000000		2.0000000		AIR				100	100	
UDS:							15.000000				'CR39'				100	100	
IC :	YES										AIR				100	100	
UCO/UCC																	
C1 :	1.3727E+01	C2 :	6.5000E+01	C3 :	1.0000E+01	C4 :	100	C5 :	100	C6 :	100	C7 :	100	C8 :	100	C9 :	100
3:	11.05704		0.500000		'CORNEA'							0		100			
4:	6.80000		2.700000		'AQUEOUS'							100		100			
STO:	5.33000		0.672500		'CORTEX'							100		100			
ASP:																	
K :	0.000000	KC :	100														
IC :	YES	CUF:	0.000000	CCF:	100												
A :	-592585E-02	B :	0.000000E+00	C :	0.000000E+00												
AC :	0	BC :	100	CC :	100	D :	0.000000E+00	DC :	100								
6:	2.65500		2.655000		'CORE'							100		100			
7:	-2.65500		0.672500		'CORTEX'							100		100			
8:	-5.33000		17.182294		'VITREOUS'							100		100			
> IMG:	-12.20000		0.000000		AIR							100		100			
SPECIFICATION DATA																	
EPD	2.00000																
DIM	MM																
WL	587.60																
REF	1																
WTW	1																
XAN	0.00000											0.00000		0.00000			
YAN	0.00000											30.00000		40.00000			
VUX	0.00000											0.00000		0.00000			
VLX	0.00000											0.00000		0.00000			
VUY	0.00000											0.00000		0.00000			
VLY	0.00000											0.00000		0.00000			

Accommodated 360 & thin +6 D lens

APERTURE DATA/EDGE DEFINITIONS

CA	
CIR S1	32.500000
CIR S2	32.500000

PRIVATE CATALOG

PWL	587.60
'CORNEA'	1.376000
'AQUEOUS'	1.336000
'CORTEX'	1.386000
'CORE'	1.406000
'VITREOUS'	1.336000
'CR39'	1.498500

REFRACTIVE INDICES

GLASS CODE	587.60
'CR39'	1.498500
'CORNEA'	1.376000
'AQUEOUS'	1.336000
'CORTEX'	1.386000
'CORE'	1.406000
'VITREOUS'	1.336000

No solves defined in system

INFINITE CONJUGATES	
EFL	23.7860
BFL	16.2232
FFL	4.1771
FNO	8.9020

AT USED CONJUGATES

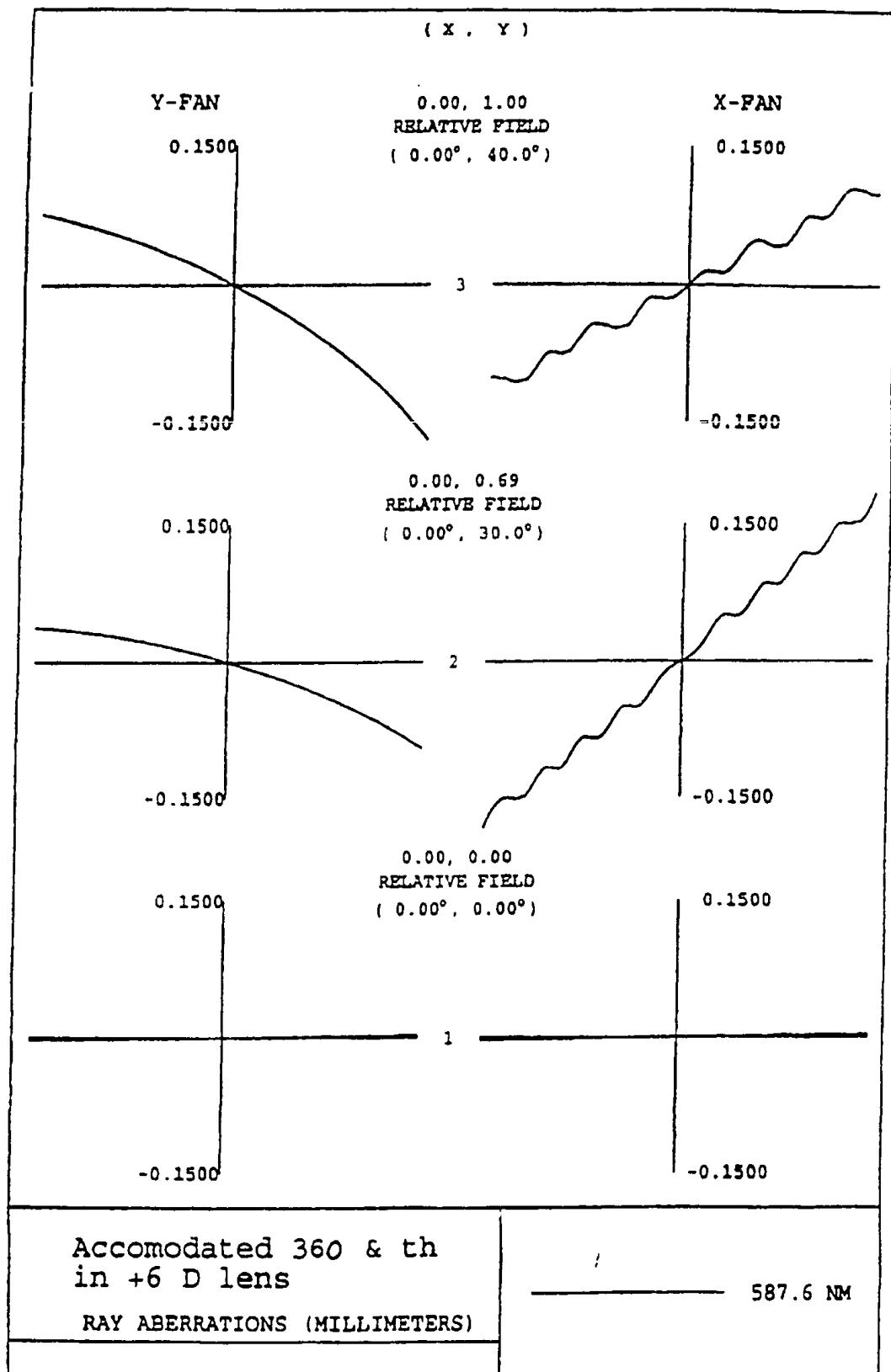
RED	0.0440
FNO	9.3635
OBJ DIS	400.0000
TT	445.7823
IMG DIS	17.1823
OAL	28.6000
PARAXIAL IMAGE	
HT	15.5590
THI	17.2710
ANG	40.0000
ENTRANCE PUPIL	
DIA	2.0000
THI	25.1299
EXIT PUPIL	
DIA	1.6994
THI	-3.9881

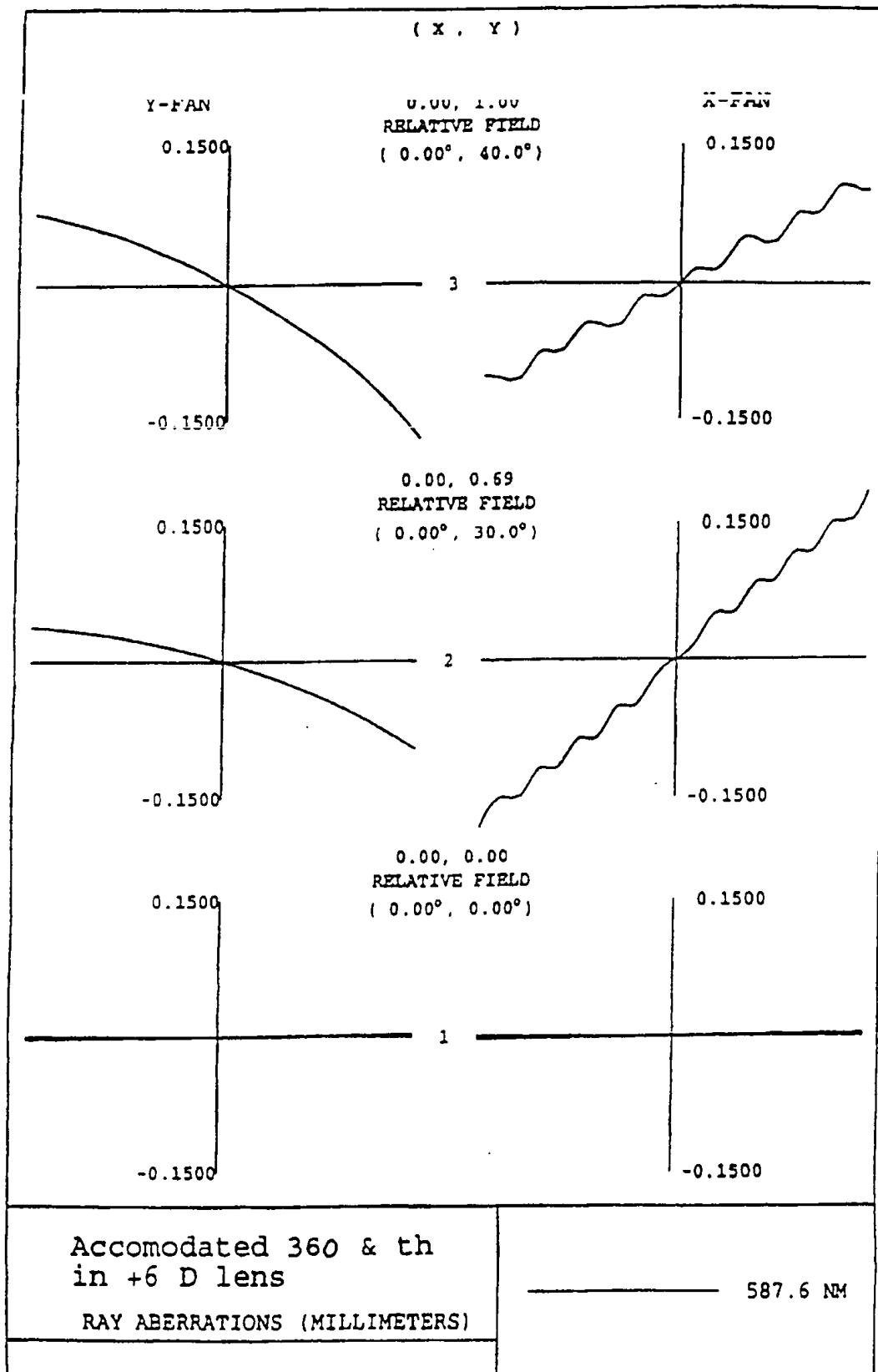
Third order aberrations

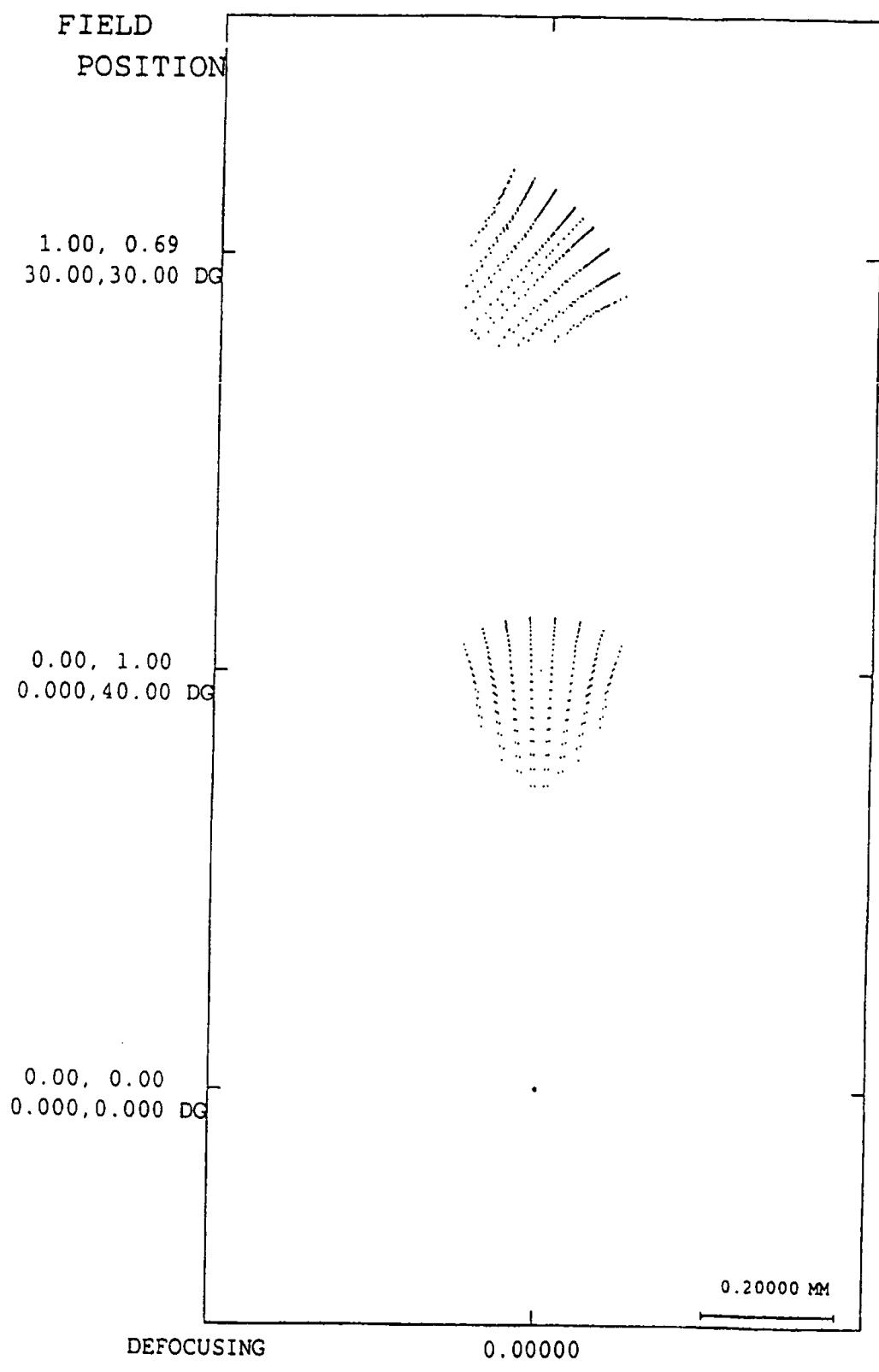
This is a non-rotationally symmetric system
first order properties and third order quantities derived from them are
probably inadequate in describing system characteristics and performance.

Accommodated 360, +6 D lens, 10 mm CA

SA	Position 1, Wavelength = 587.6 NM	SAS	PTB	DST	AX	LAT	PTZ		
1	-0.000006	-0.000800	-0.059778	-0.037179	-0.025880	-1.575421	0.000000	0.000000	-0.004004
2	0.000000	0.000150	-0.043472	-0.014491	0.000000	4.207150	0.000000	0.000000	0.000000
3	-0.000672	-0.019506	-0.348136	-0.222399	-0.159531	-2.150435	0.000000	0.000000	-0.024682
4	0.000293	0.003827	0.037372	0.026245	0.020682	0.114455	0.000000	0.000000	0.003200
STO	-0.000656	-0.011574	-0.100788	-0.055426	-0.032745	-0.325842	0.000000	0.000000	-0.005066
	0.009494	0.000000	0.000000	0.000000	0.000000	0.000000	ASPHERIC CONTRIBUTIONS		
6	-0.002635	-0.026948	-0.116858	-0.055610	-0.024985	-0.189589	0.000000	0.000000	-0.003866
7	-0.003997	-0.007551	-0.029740	-0.026570	-0.024985	-0.016731	0.000000	0.000000	-0.003866
8	-0.001820	0.005935	-0.039196	-0.034895	-0.032745	0.037936	0.000000	0.000000	-0.005066
SUM	0.000000	-0.056468	-0.700597	-0.420325	-0.280188	0.101523	0.000000	0.000000	-0.043349

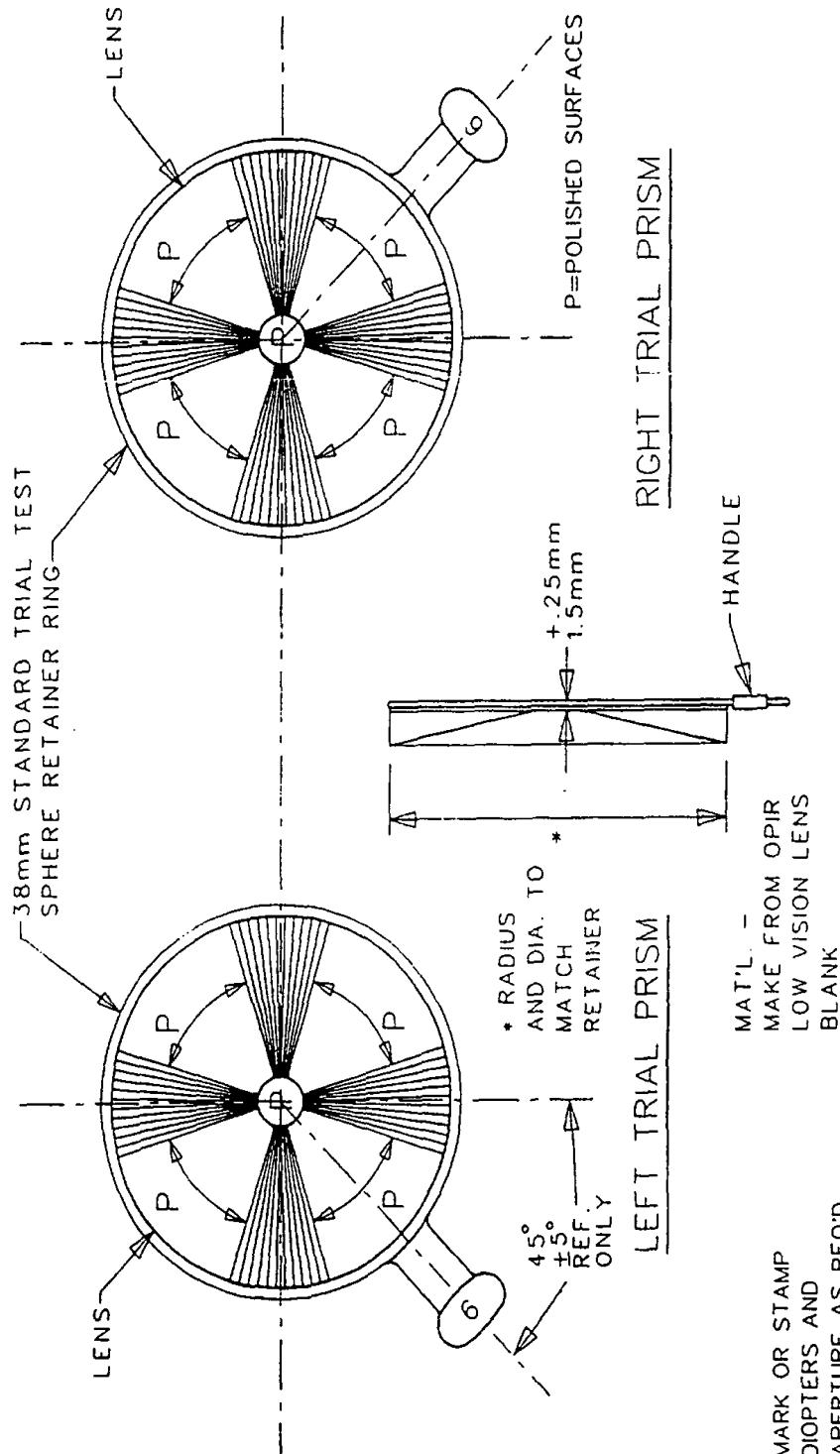






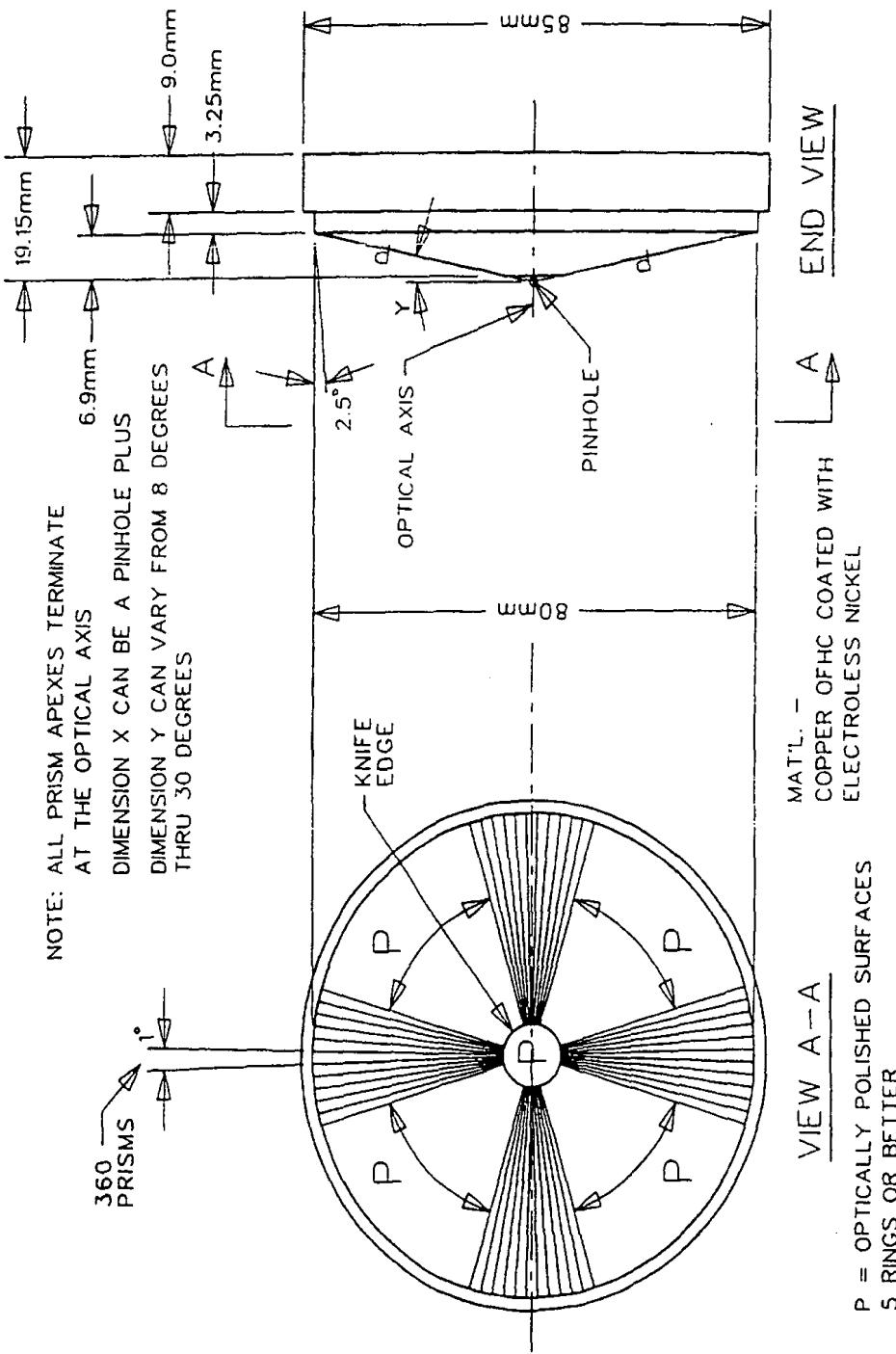
Accomodated 360 & thin +6 D lens

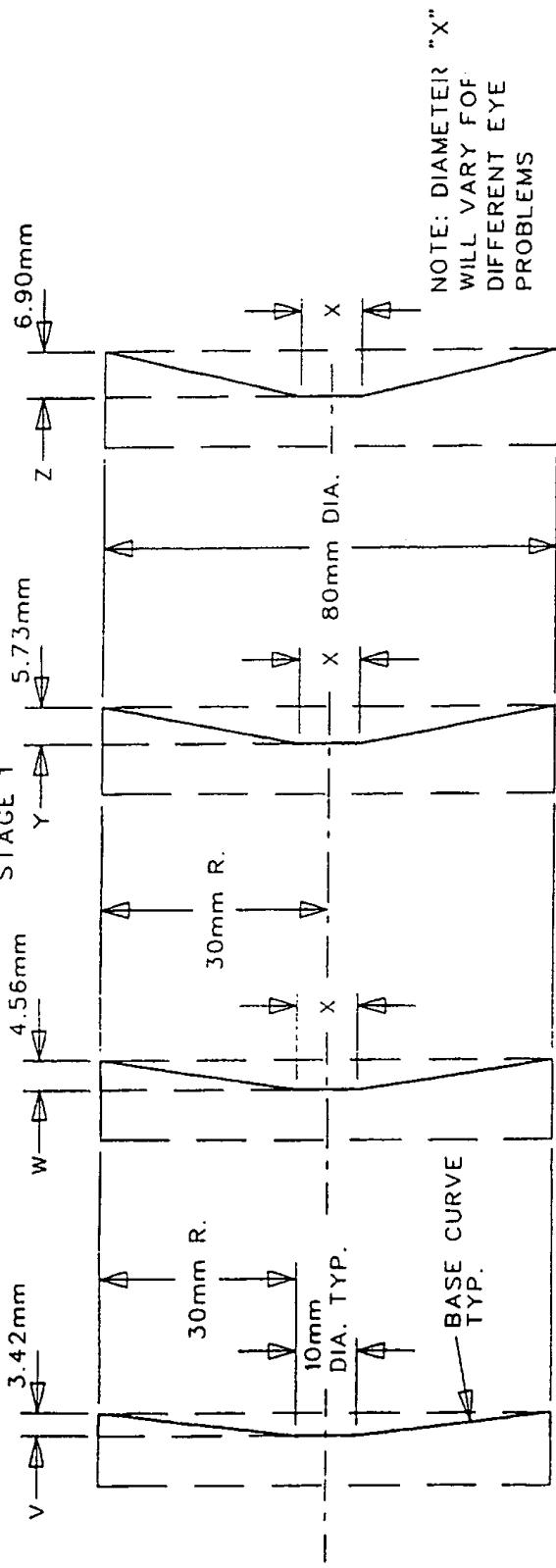
TYPICAL 360 OPIR FIELD EXPANDING TRIAL TEST PRISM
FOR LOW VISION REFRACTING



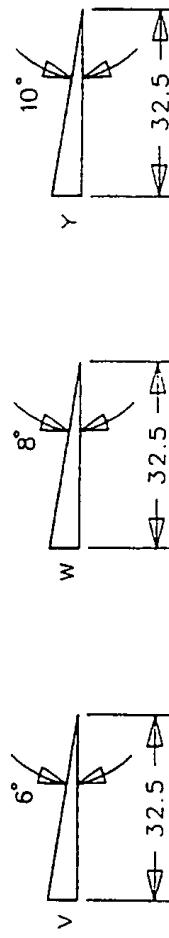
TYPICAL 360 MOLD FOR COMMERCIAL CONICAL LENSES

STAGE 1



TYPICAL OPIR 360 LENS BLANKS FOR LOW VISION GLASSES

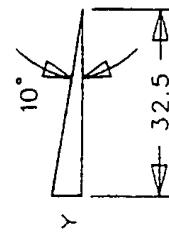
6 DIOPTER PRISMS



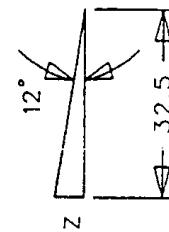
8 DIOPTER PRISMS



10 DIOPTER PRISMS

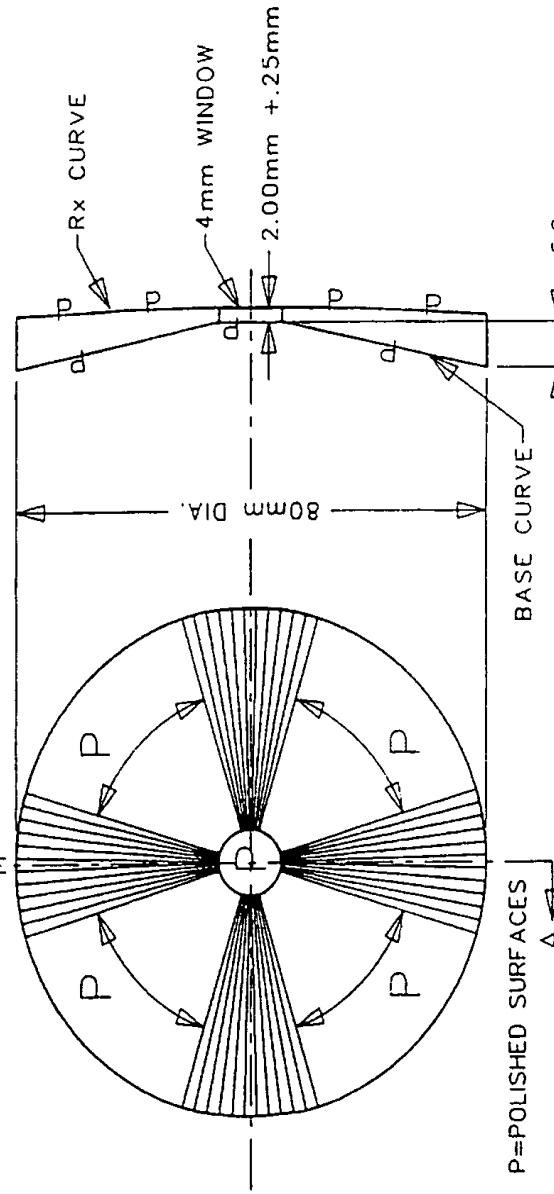


12 DIOPTER PRISMS



$$\begin{aligned}
 V &= (\tan 6^\circ) (32.5) & W &= (\tan 8^\circ) (32.5) & Y &= (\tan 10^\circ) (32.5) & Z &= (\tan 12^\circ) (32.5) \\
 V &= (.10510) (32.5) & W &= (.14054) (32.5) & Y &= (.17633) (32.5) & Z &= (.21256) (32.5) \\
 V &= 3.42mm & W &= 4.56mm & Y &= 5.73mm & Z &= 6.90mm
 \end{aligned}$$

TYPICAL OPIR 360 LENS FOR LOW VISION GLASSES



P=POLISHED SURFACES

ALL SURFACES MARKED P
MUST MEET THE OPTICAL
REQUIREMENT OF THE AMERICAN
NATIONAL STANDARDS FOR
OPHTHALMIC PLASTIC

$$\frac{\text{VIEW A-A}}{\text{MAT'L. - OPHTHALMIC
PLASTIC - CR-39 OR
EQUIVALENT HAVING A
N VALUE OF 1.498
OR BETTER}}$$

$$\gamma = \frac{.3492\text{mm}}{(.3492)} = .698\text{mm}$$

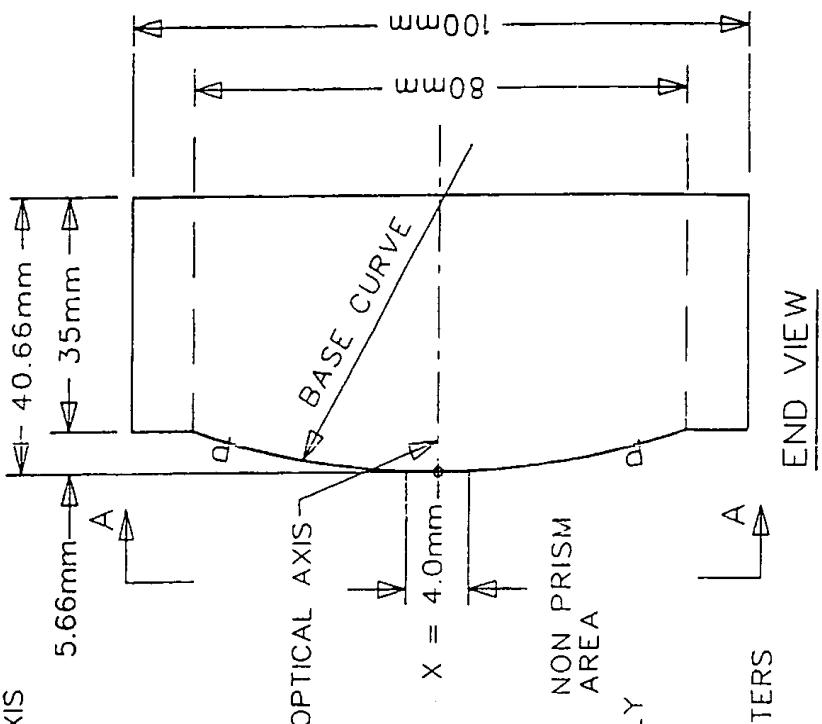
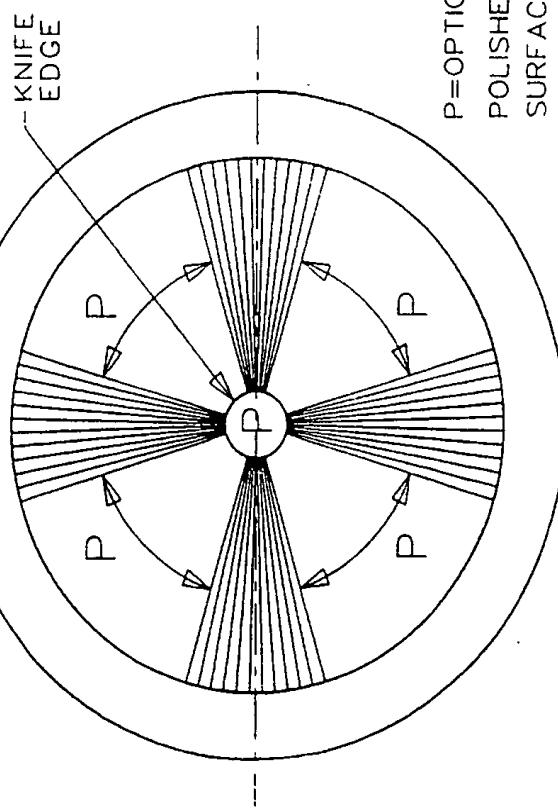
TYPICAL OPIR 360 MOLD FOR LOW VISION GLASSES

STAGE 1

$$SAG = \frac{1/2D^2}{2R} =$$

$$\frac{4.0^2}{(2)(141.3)} = \frac{1600}{282.6} = 5.66$$

NOTE: ALL PRISM APEXES TERMINATE
AT THE OPTICAL AXIS



VIEW A-A

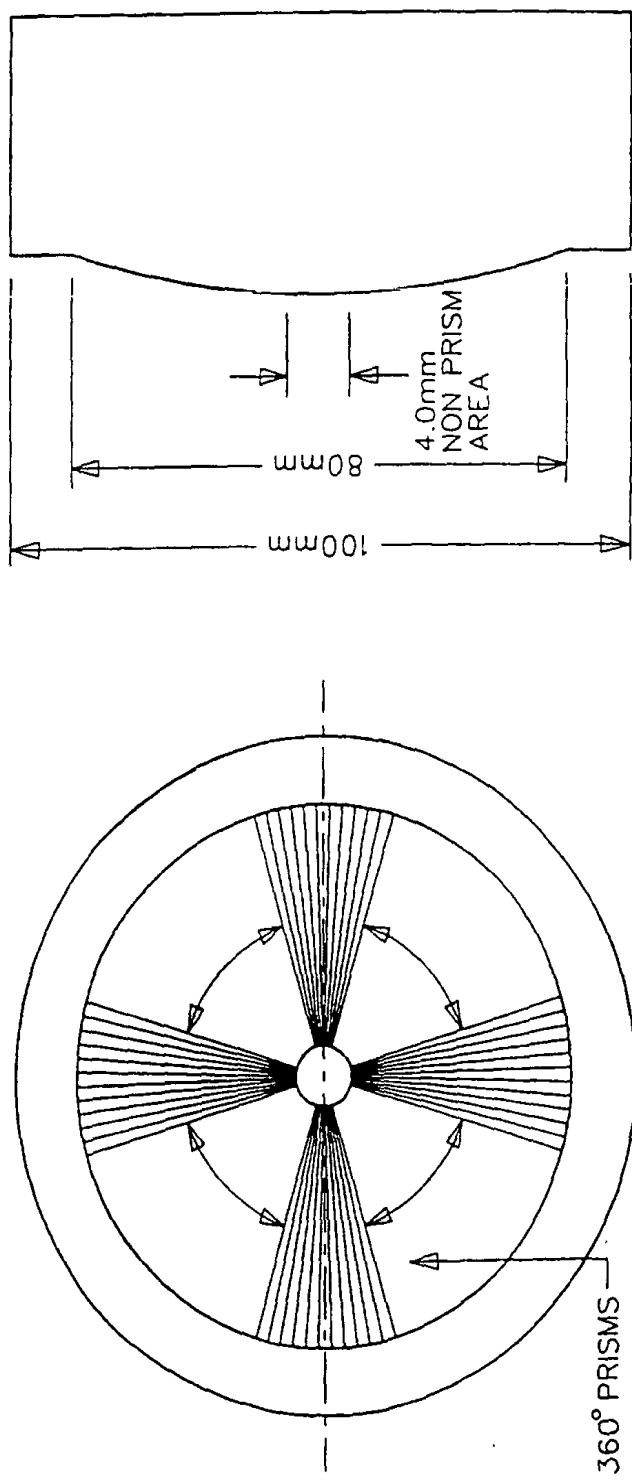
MAT'L. -

COPPER OFHC COATED WITH
ELECTROLESS NICKEL

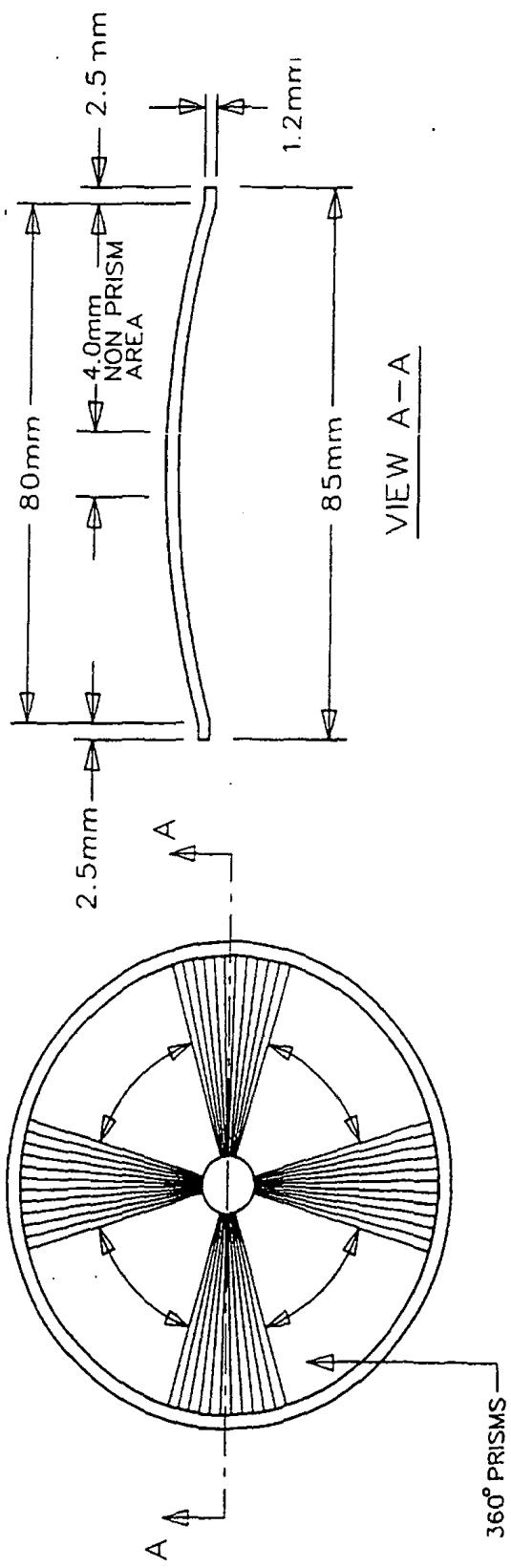
END VIEW

TYPICAL OPIR 360 MOLD FOR LOW VISION GLASSES

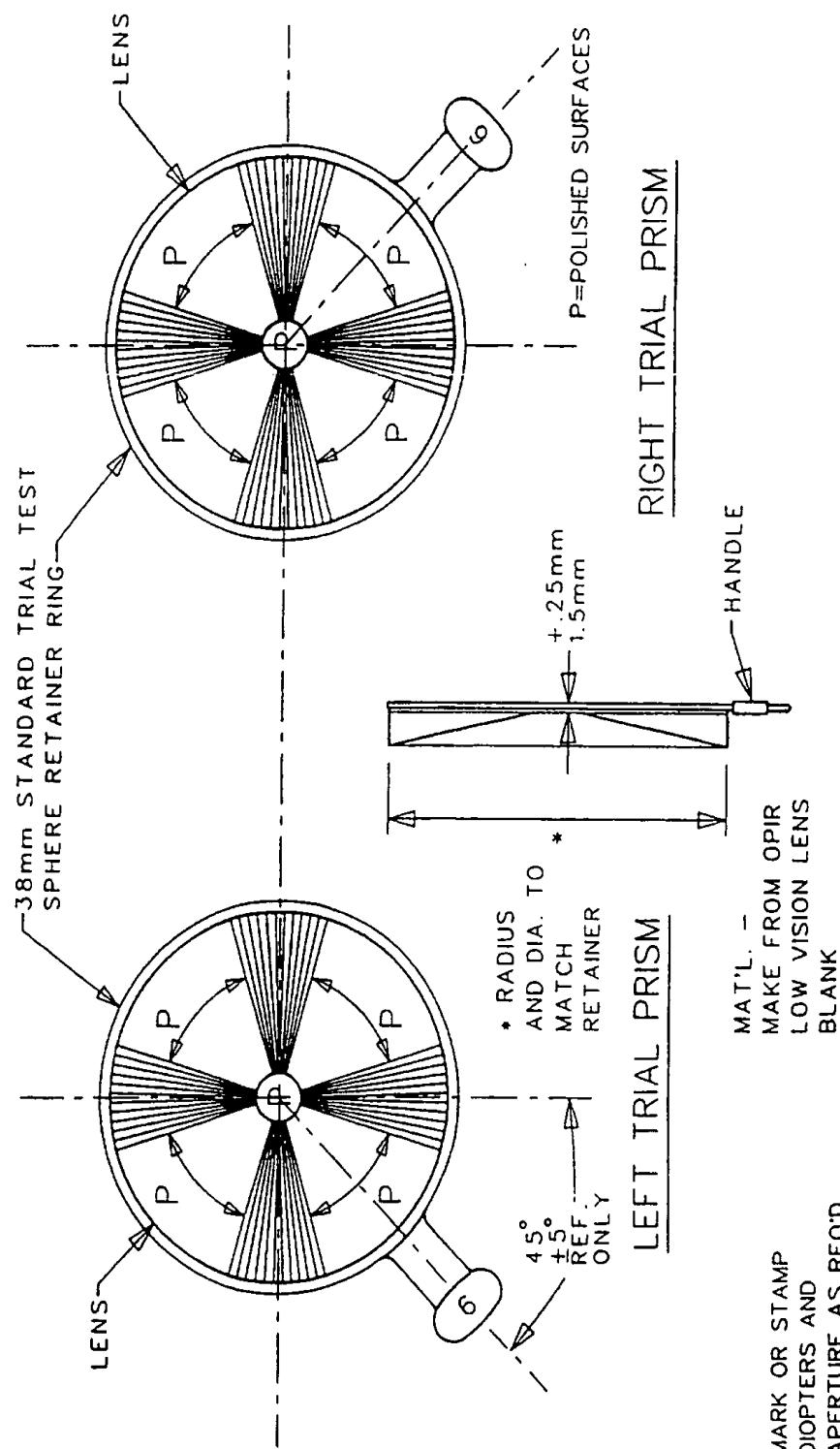
STAGE 2



TYPICAL OPIR 360 MOLD FOR LOW VISION GLASSES
STAGE 3

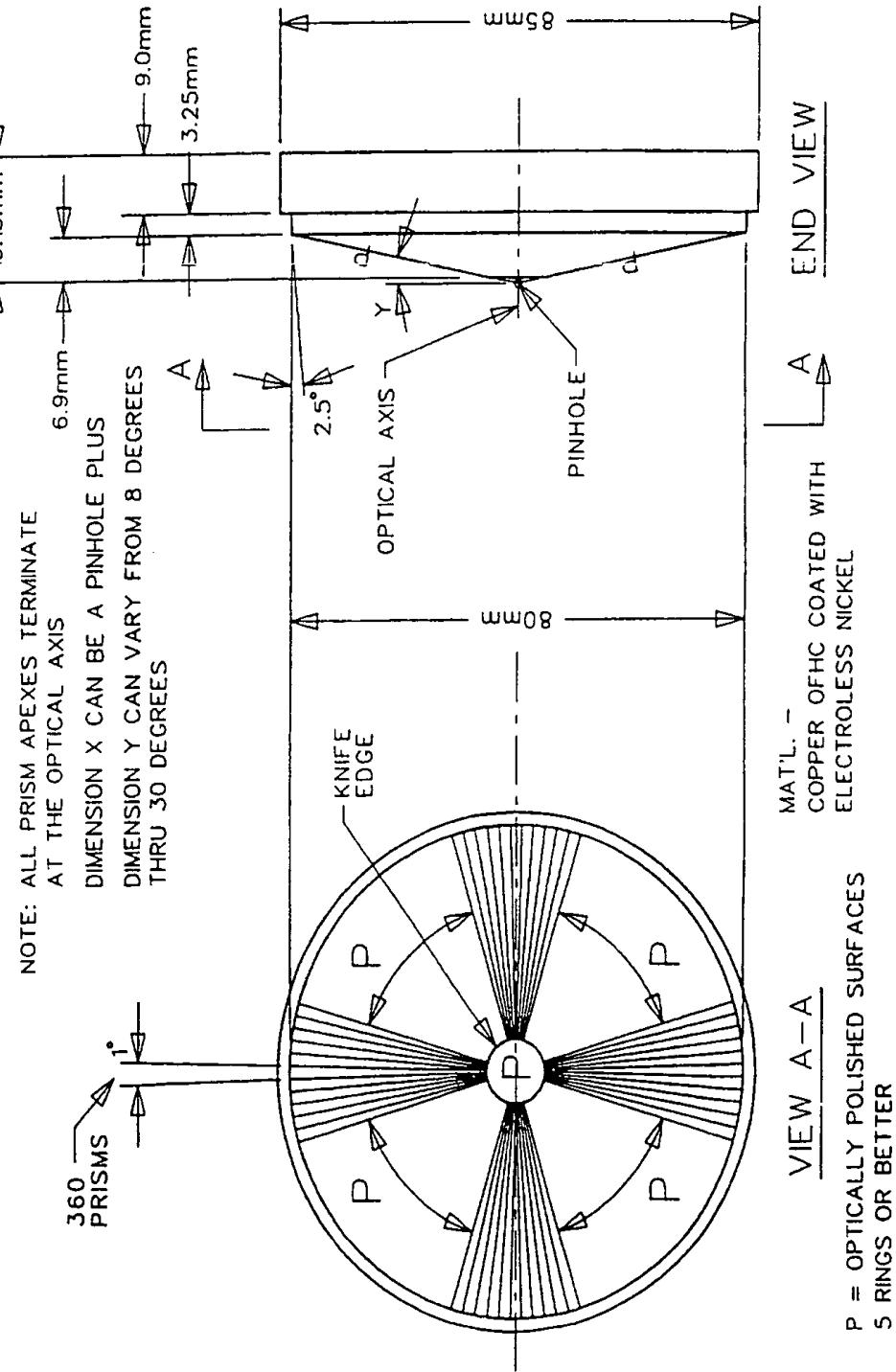


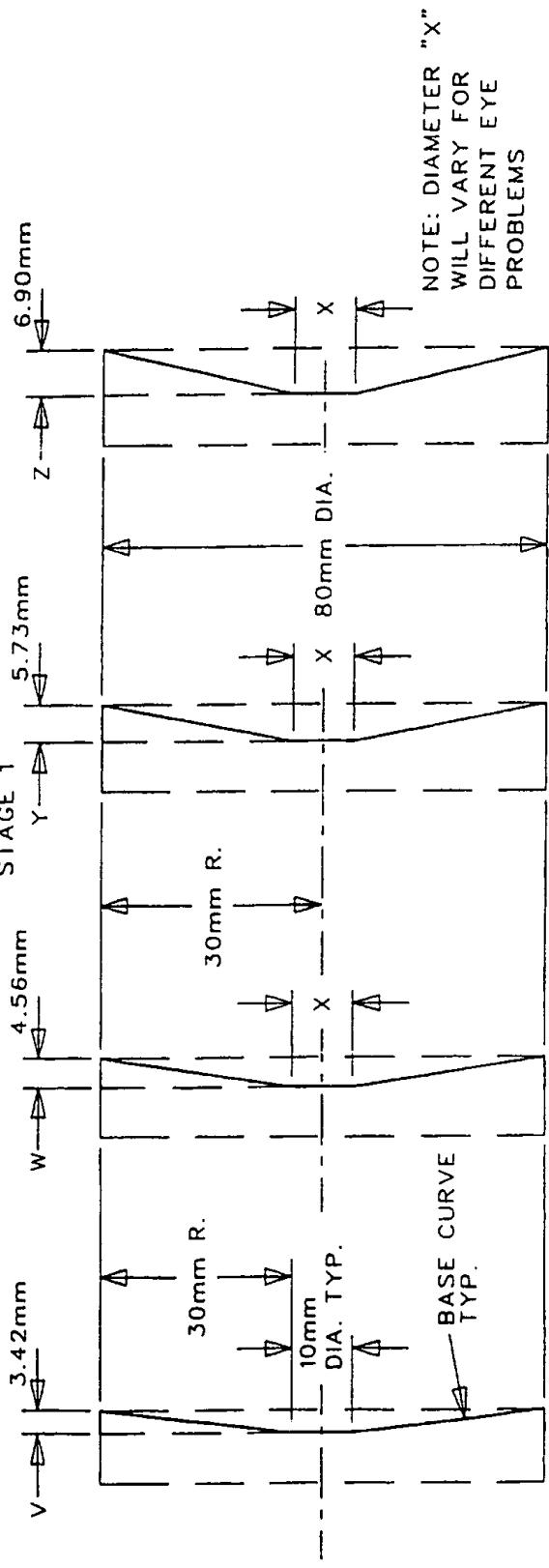
TYPICAL 360 OPIR FIELD EXPANDING TRIAL TEST PRISMS
FOR LOW VISION REFRACTING



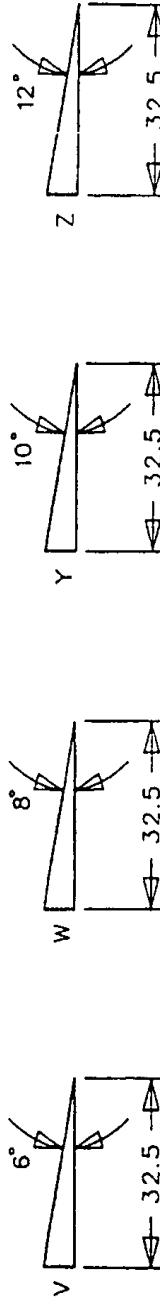
TYPICAL 360 MOLD FOR COMMERCIAL CONICAL LENSES

STAGE 1



TYPIICAL OPIR 360 LENS BLANKS FOR LOW VISION GLASSES

6 DIOPTER PRISMS 8 DIOPTER PRISMS 10 DIOPTER PRISMS

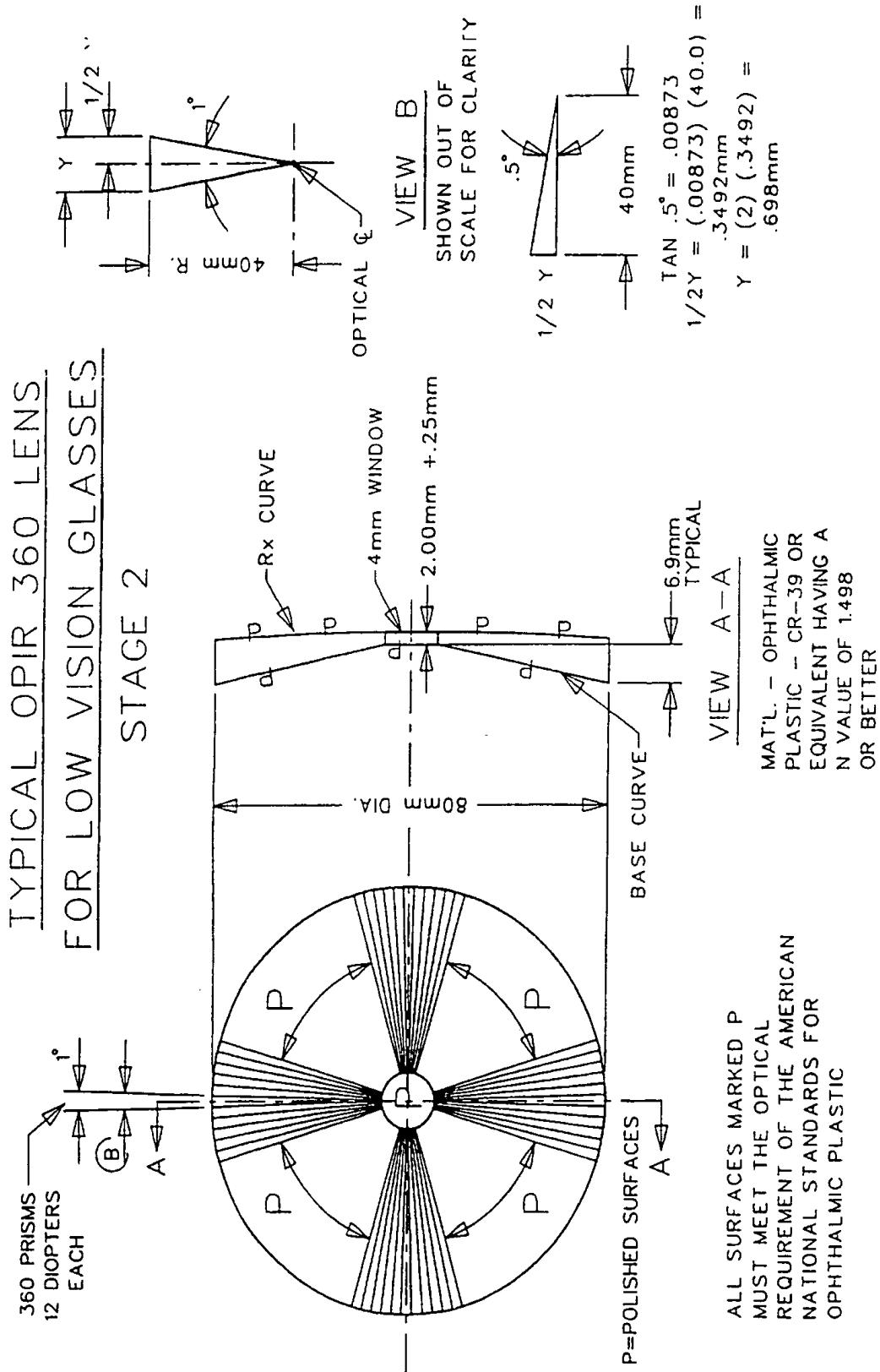


12 DIOPTER PRISMS



12 DIOPTER PRISMS

$$\begin{aligned}
 V &= (\tan 6^\circ) (32.5) & W &= (\tan 8^\circ) (32.5) & Y &= (\tan 10^\circ) (32.5) & Z &= (\tan 12^\circ) (32.5) \\
 V &= (.10510) (32.5) & W &= (.14054) (32.5) & Y &= (.17633) (32.5) & Z &= (.21256) (32.5) \\
 V &= 3.42\text{mm} & W &= 4.56\text{mm} & Y &= 5.73\text{mm} & Z &= 6.90\text{mm}
 \end{aligned}$$



TYPICAL OPIR 360 MOLD FOR LOW VISION GLASSES

STAGE 1

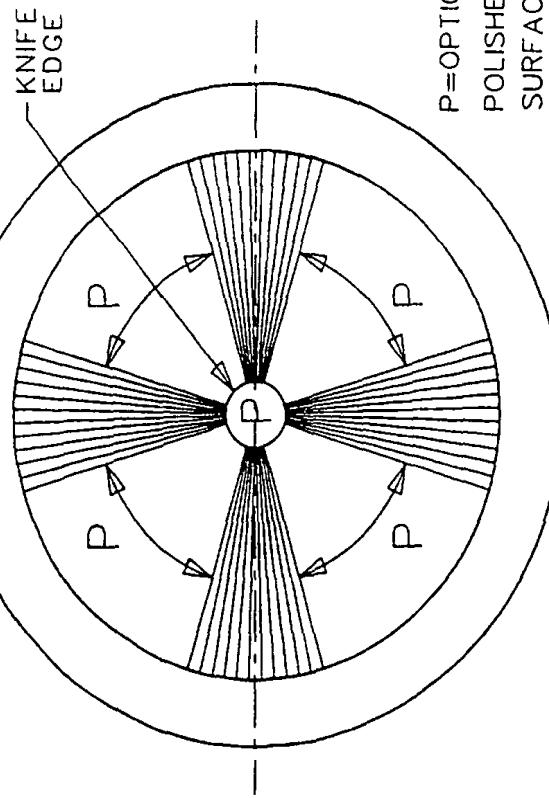
$$SAG = \frac{1/2D^2}{2R} =$$

$$\frac{40^2}{1600} =$$

$$\frac{(2)(141.3)}{282.6} = 5.66$$

$$1^{\circ} \rightarrow 360 \text{ PRISMS}$$

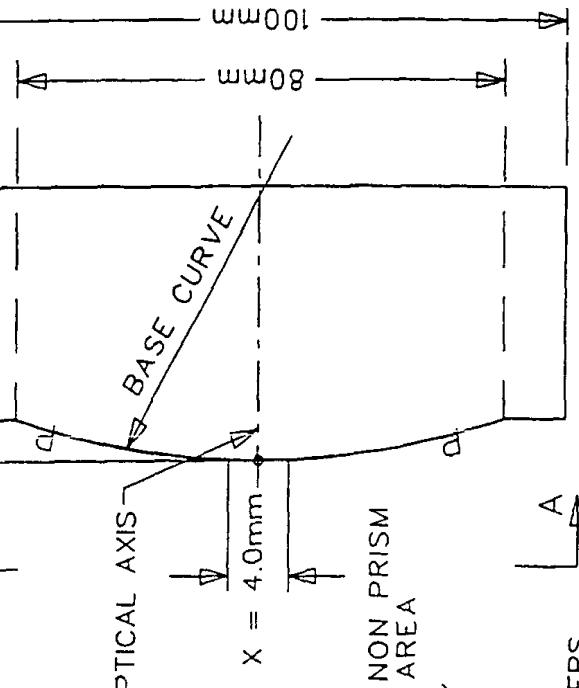
NOTE: ALL PRISM APEXES TERMINATE
AT THE OPTICAL AXIS



VIEW A-A

END VIEW

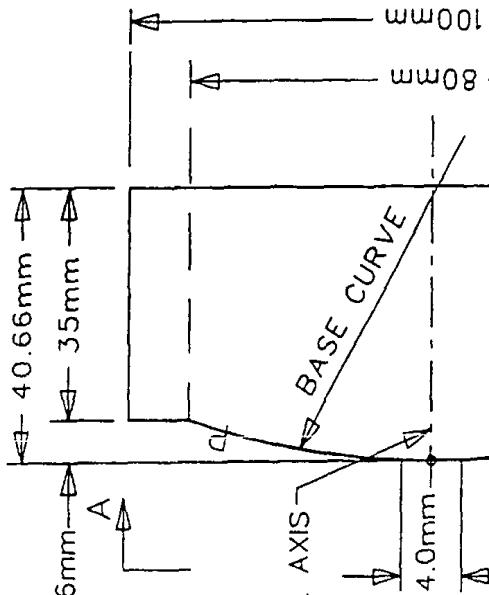
MAT'L. —
COPPER OFHC COATED WITH
ELECTROLESS NICKEL



NON PRISM
AREA

$$X = 4.0\text{mm}$$

OPTICAL
AXIS



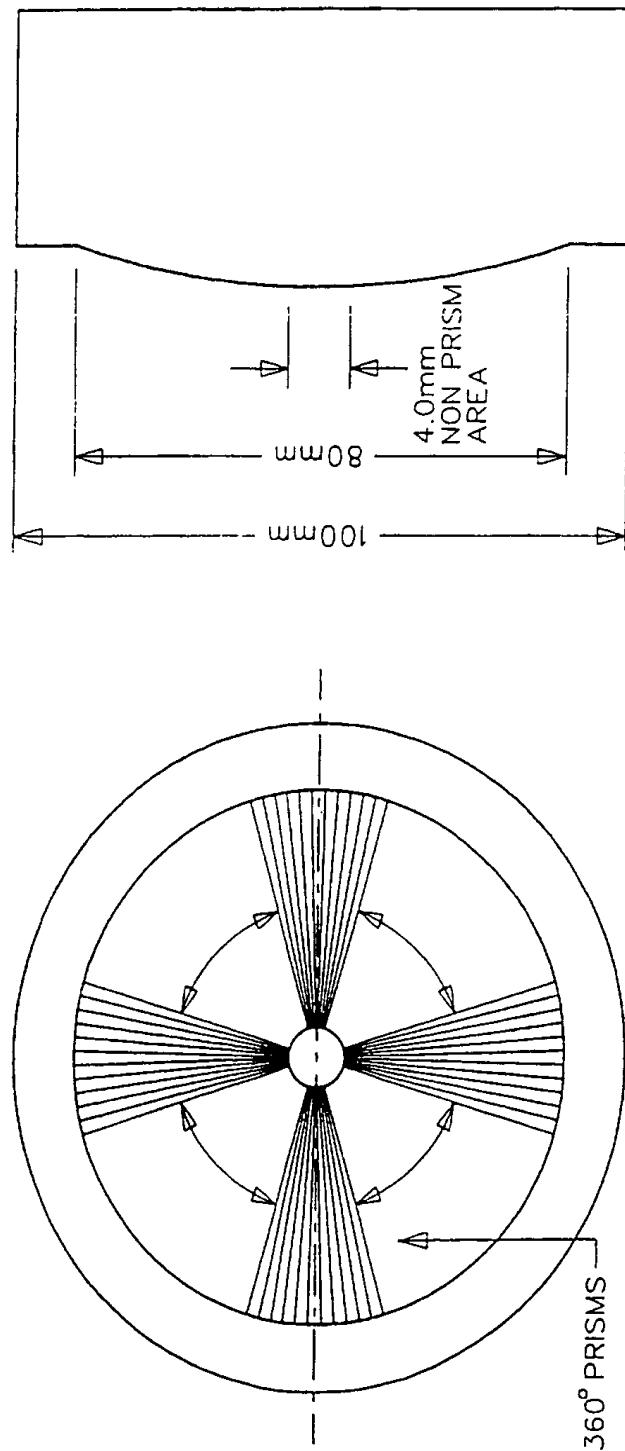
40.66mm
35mm

$$5.66\text{mm}$$

100mm
80mm

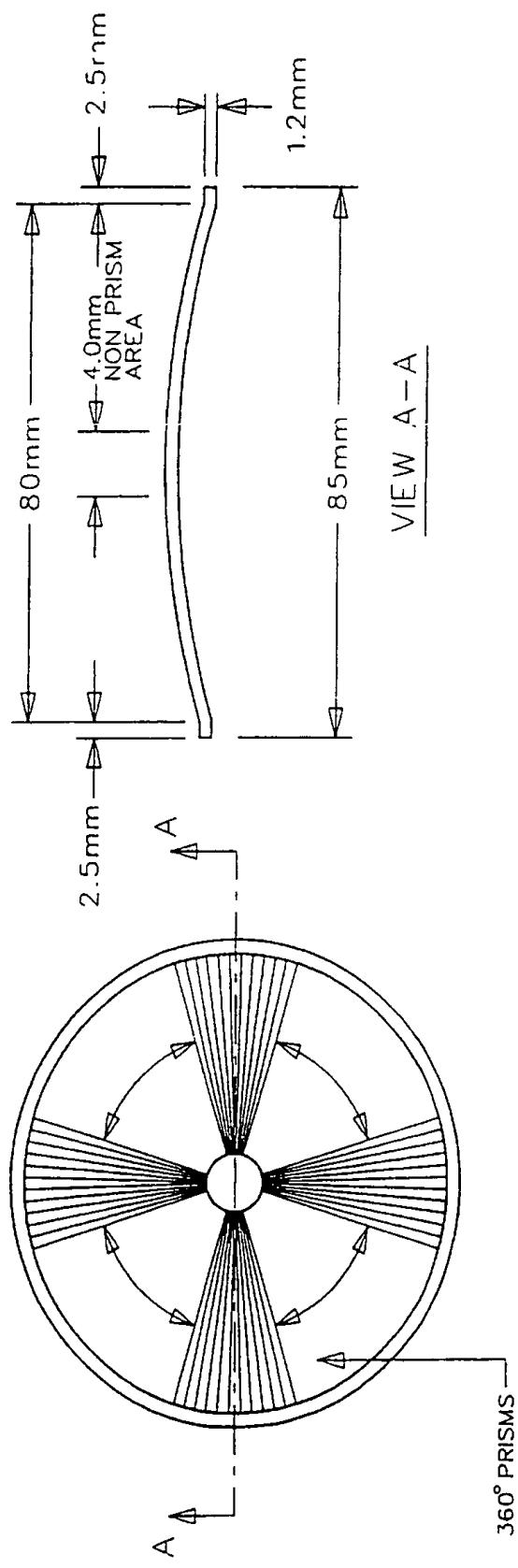
TYPICAL OPIR 360 MOLD FOR LOW VISION GLASSES

STAGE 2



Figure

TYPICAL OPIR 360 MOLD FOR LOW VISION GLASSES
STAGE 3



Claims:

1. A prismatic lens, comprising:
 - (a) a lens member having a non prism area and a plurality of prisms circumscribing the non prism area, each of the plurality of prisms having a base and an apex portion, the apex portion disposed intermediate of the base and the non prism area, and each prism contiguous to a pair of prisms.
- 5 2. The prismatic lens of Claim 1, wherein the non prism area includes a clear aperture.
3. The prismatic lens of Claim 1, wherein the lens member includes a substantially conical surface.
4. The prismatic lens member of Claim 1, wherein the lens member includes a substantially spherical surface.
5. The prismatic lens member of Claim 1, wherein the lens member includes an aspheric surface.
6. The prismatic lens member of Claim 1, wherein the non prism area has a diameter of approximately .0001 millimeters to approximately 25 millimeters.
7. The prismatic lens member of Claim 1, wherein the prisms define a portion of a substantially spherical surface.
8. The prismatic lens member of Claim 1, wherein the prisms define a portion of a substantially conical surface.
9. The prismatic lens member of Claim 1, wherein the prisms define a portion of a substantially aspheric surface.
10. The prismatic lens member of Claim 1, wherein the non prism area is sized to a functional retina.
11. The prismatic lens member of Claim 1, wherein the lens member is a contact lens.
12. The prismatic lens member of Claim 1, wherein the prismatic lens member includes an object side and an image side, the prisms formed on one of the object and the image side and a

vision correcting curvature formed on a remaining of the object

5 and the image side.

13. The prismatic lens of Claim 1, wherein the prisms and a curvature of the lens member are selected to preclude minification and magnification of an image passing through the lens.

14. The prismatic lens of Claim 1, wherein an optical axis of the lens member pass through the non prism area.

15. The prismatic lens member of Claim 1, wherein the prisms have an equal diopter.

16. A method of forming an image enhancing lens, comprising:

(a) forming a plurality of prism forming surfaces in an apex portion in, base out orientation about a non prism area; and

5 (b) disposing an optical material in contact with the prism forming surfaces to form a plurality of prismatic elements disposed about a non prism area in an apex portion in-base out orientation.

17. The method of Claim 16, wherein forming the plurality of prism forming surfaces includes disposing the surfaces on a substantially spherical surface.

18. The method of Claim 16, wherein forming the plurality of prism forming surfaces includes disposing the surfaces on a substantially conical surface.

19. The method of Claim 16, wherein forming the plurality of prism forming surfaces includes disposing the surfaces on a substantially aspheric surface.

1/19

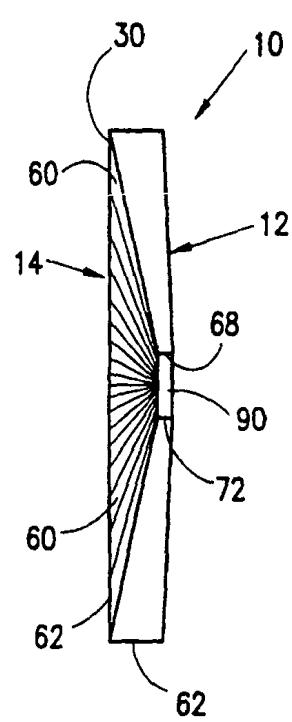


FIG. 1

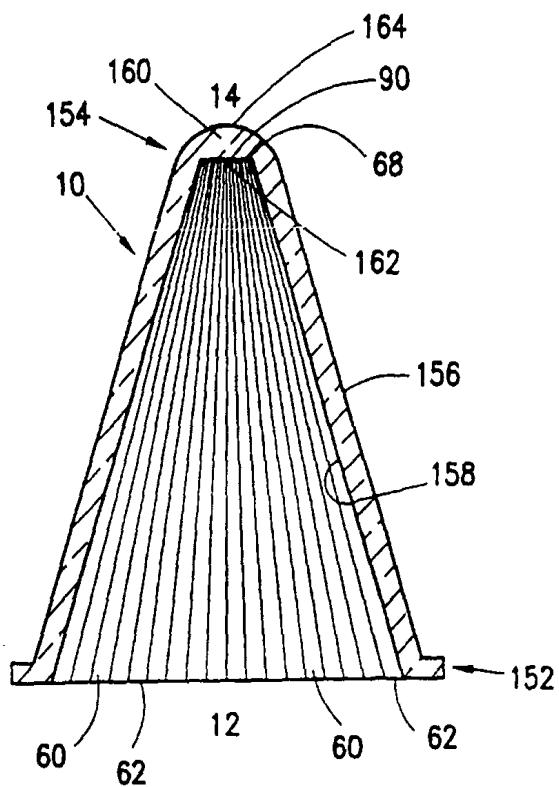


FIG. 2

2/19

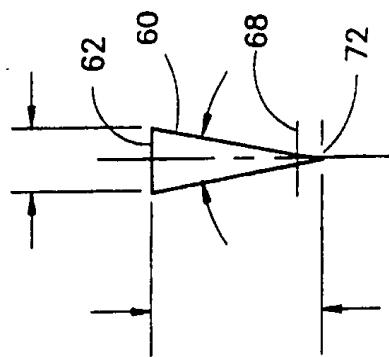


FIG. 5

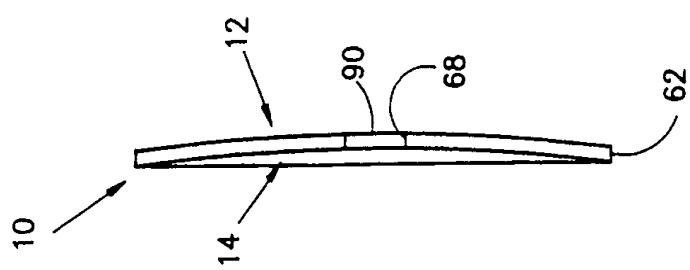


FIG. 4

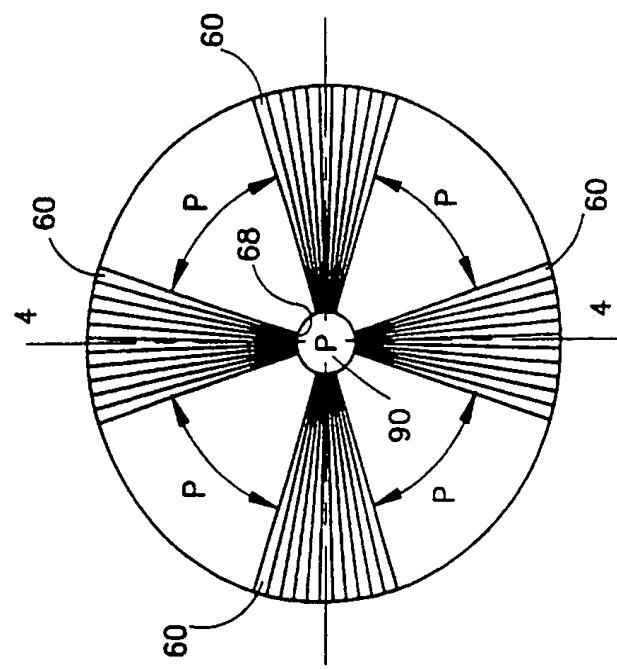


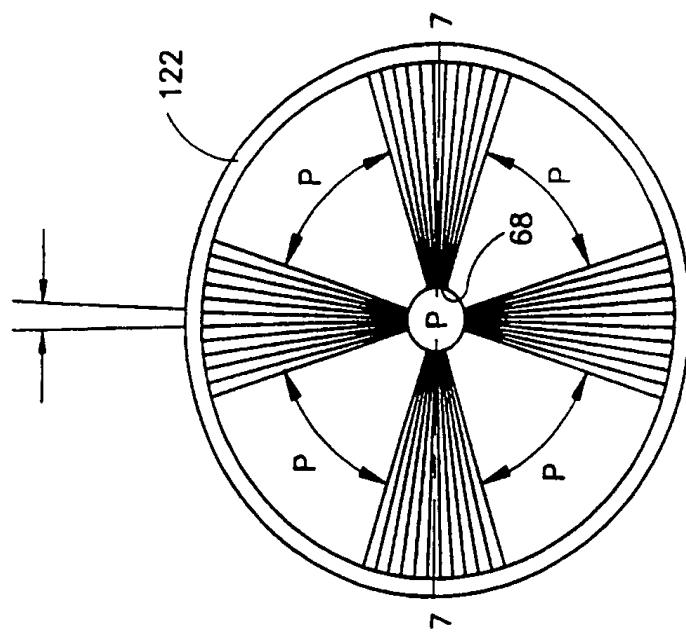
FIG. 3

3/19

FIG. 7



FIG. 6



4/19

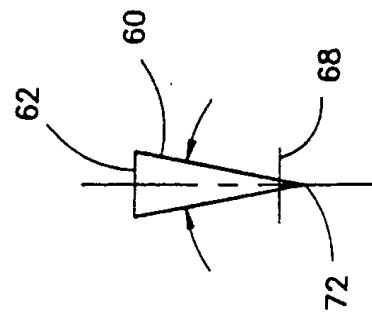


FIG. 10

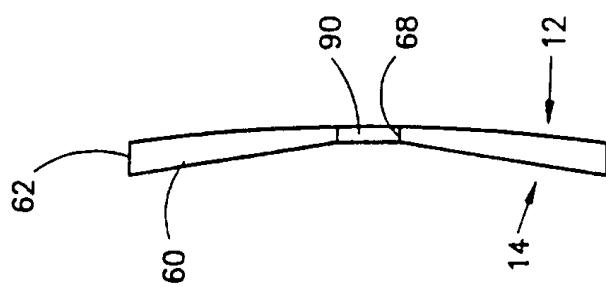


FIG. 9

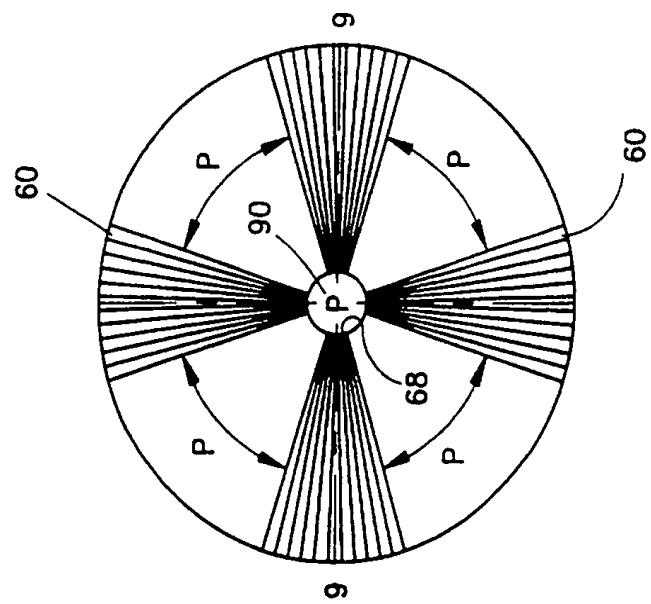


FIG. 8

5/19



FIG. 12

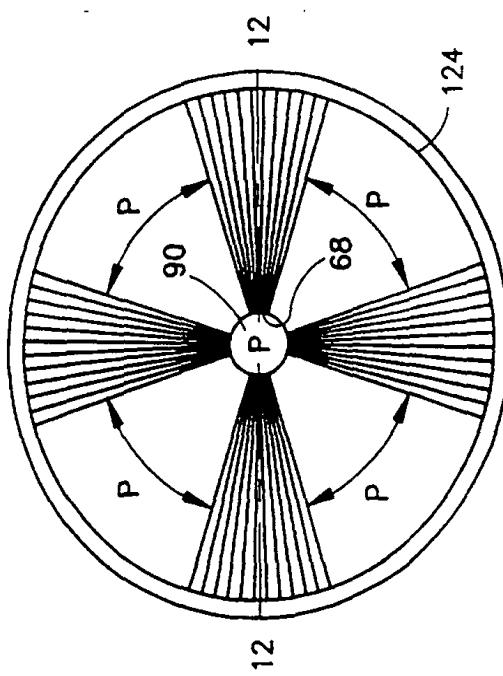


FIG. 11

6/19

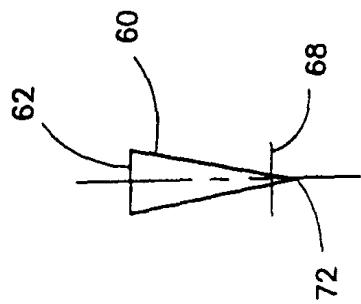


FIG. 15

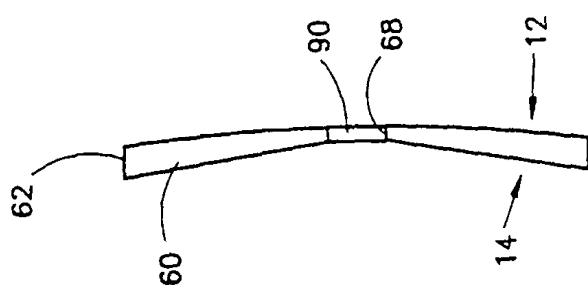


FIG. 14

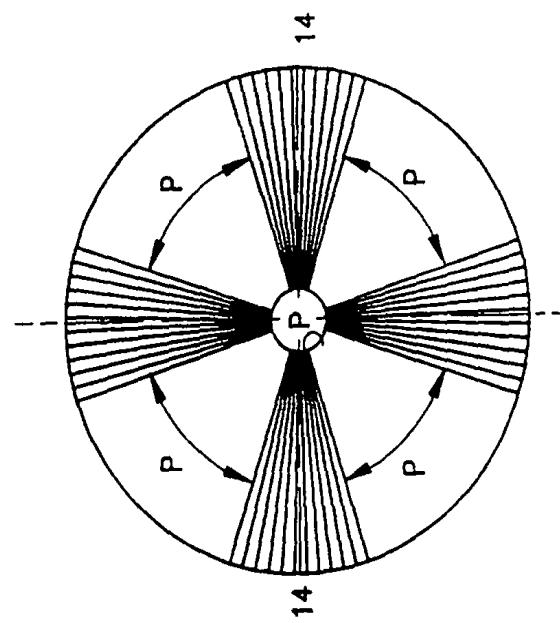


FIG. 13

7/19

FIG. 17

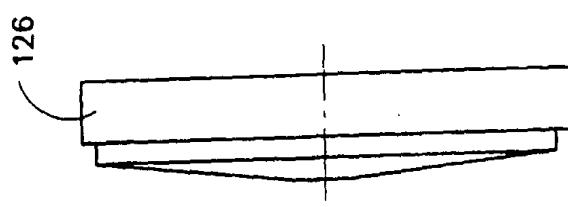
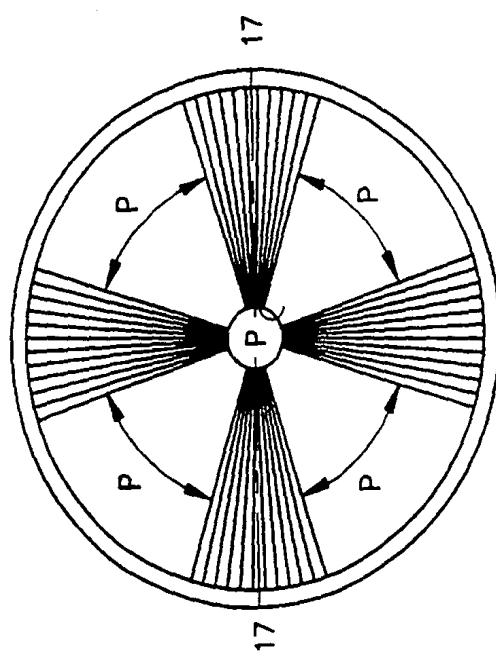


FIG. 16



8/19

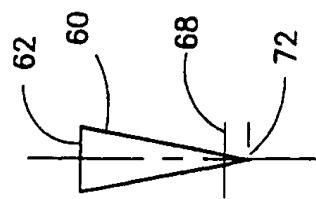


FIG. 20

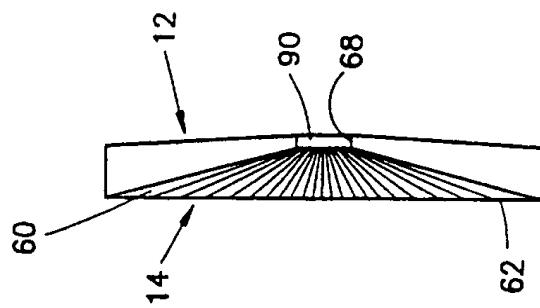


FIG. 19

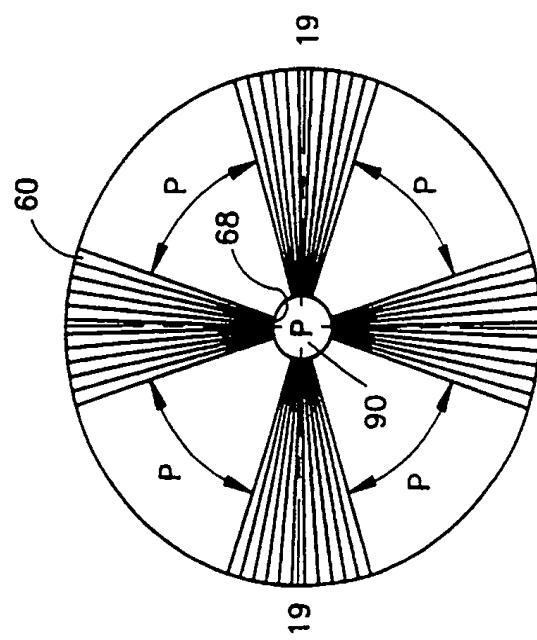


FIG. 18

9/19

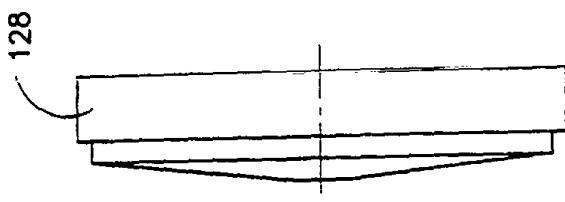


FIG. 22

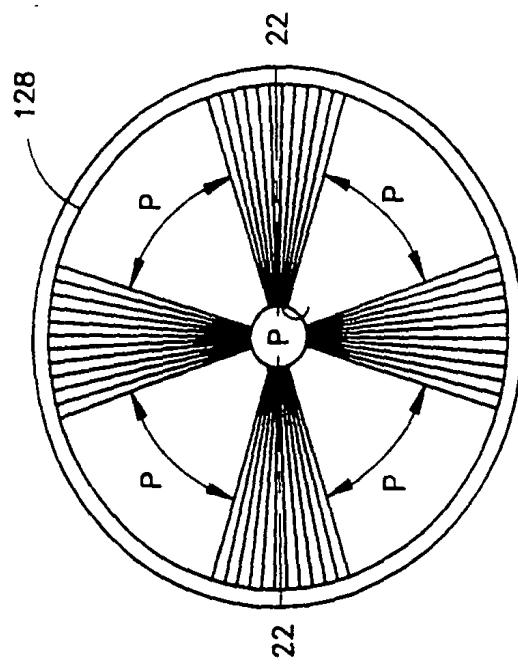


FIG. 21

10/19

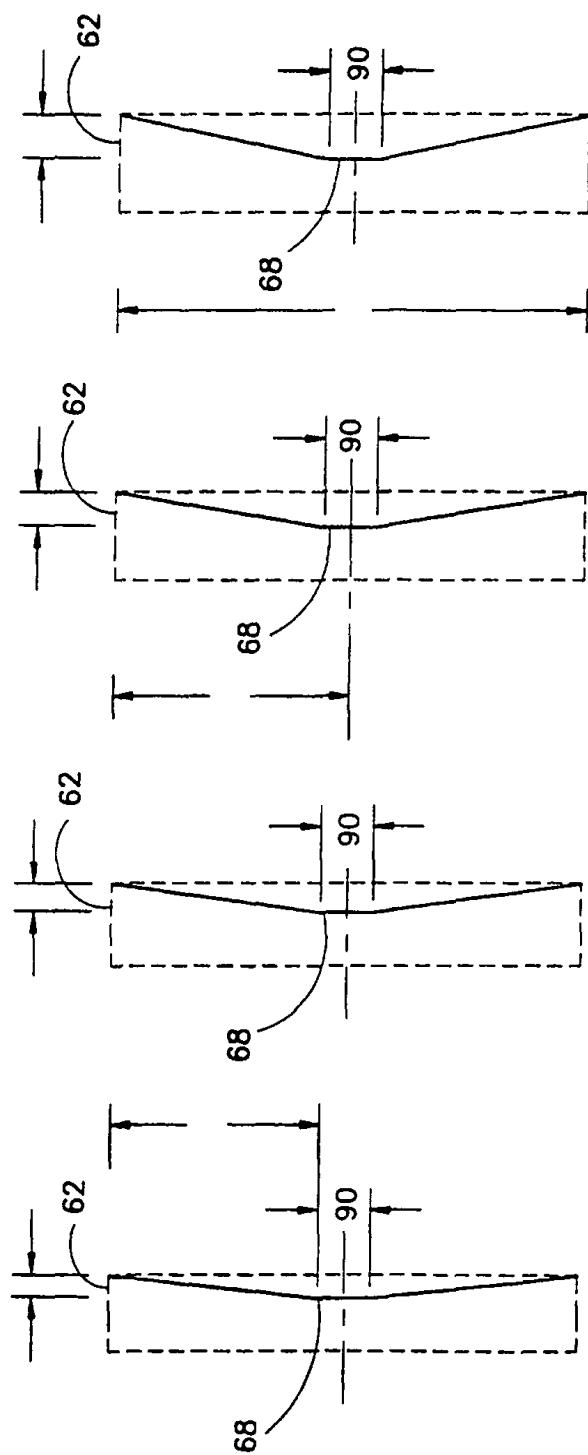


FIG. 23 FIG. 24 FIG. 25 FIG. 26

11/19

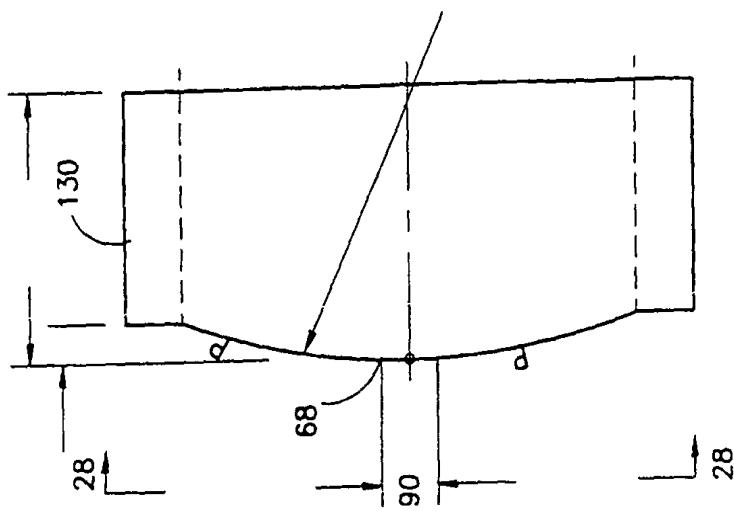


FIG. 27

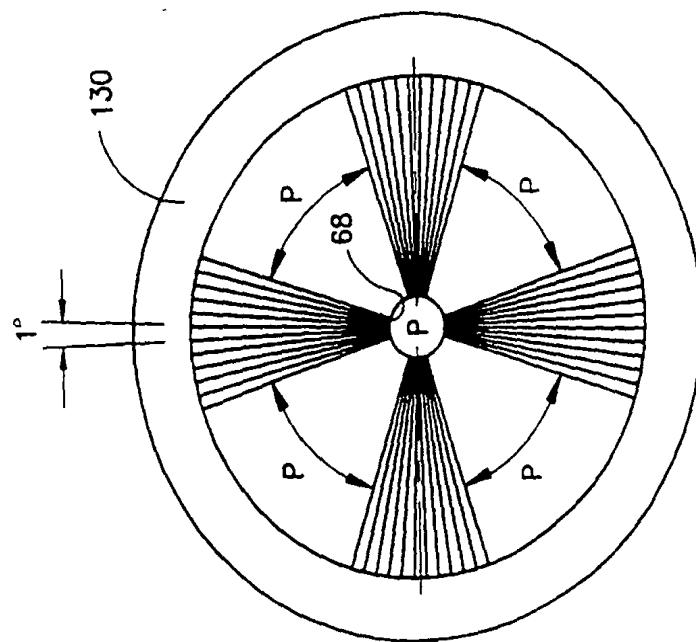


FIG. 28

12/19

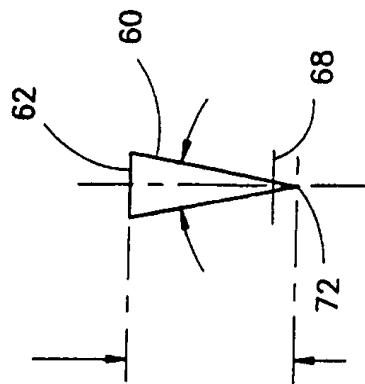


FIG. 31

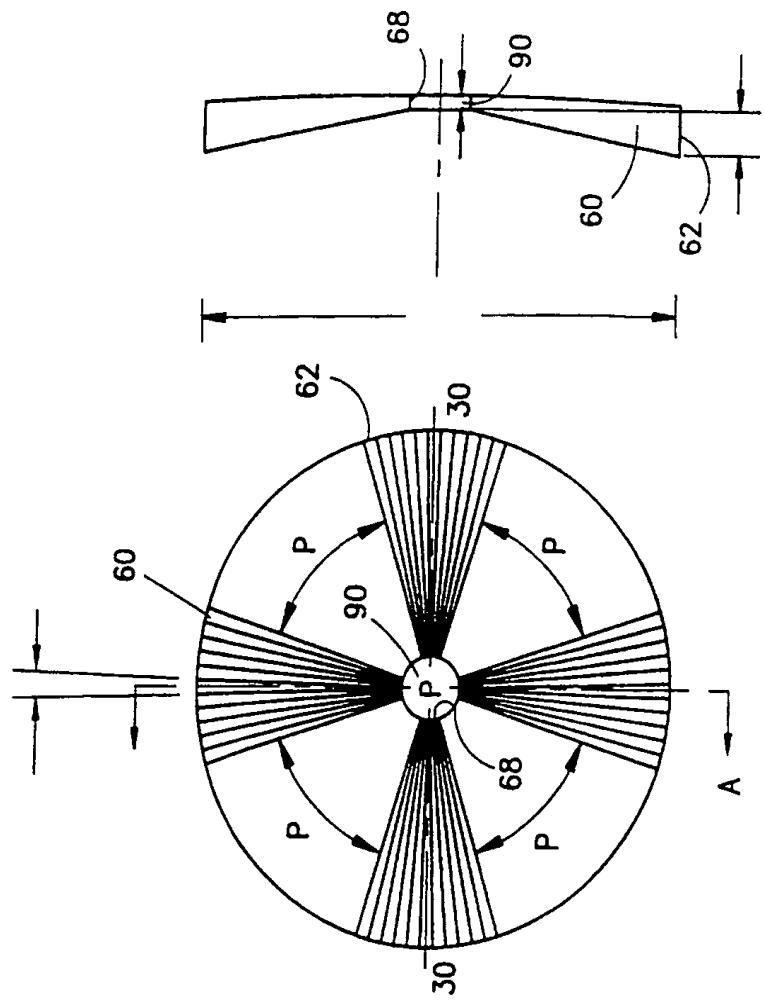
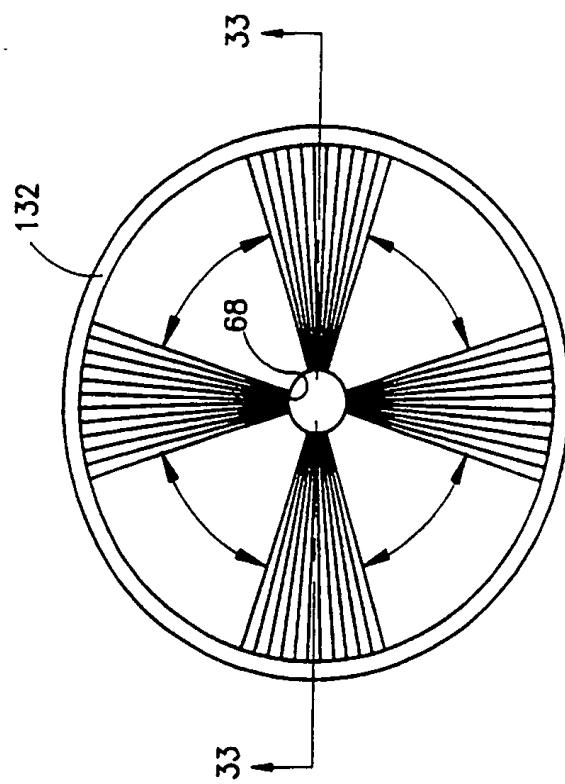
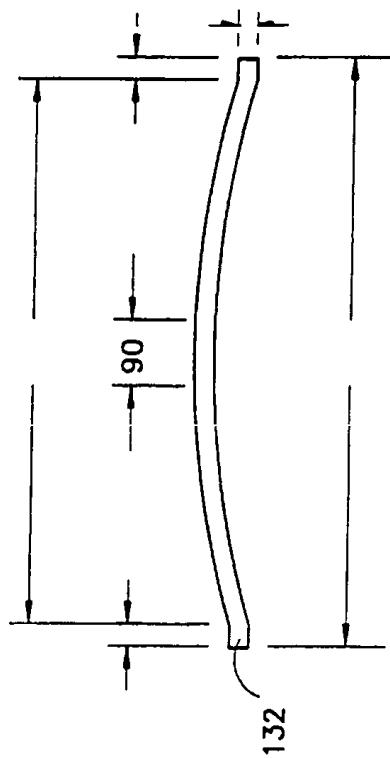


FIG. 29

FIG. 30

13/19



SUBSTITUTE SHEET (RULE 26)

14/19

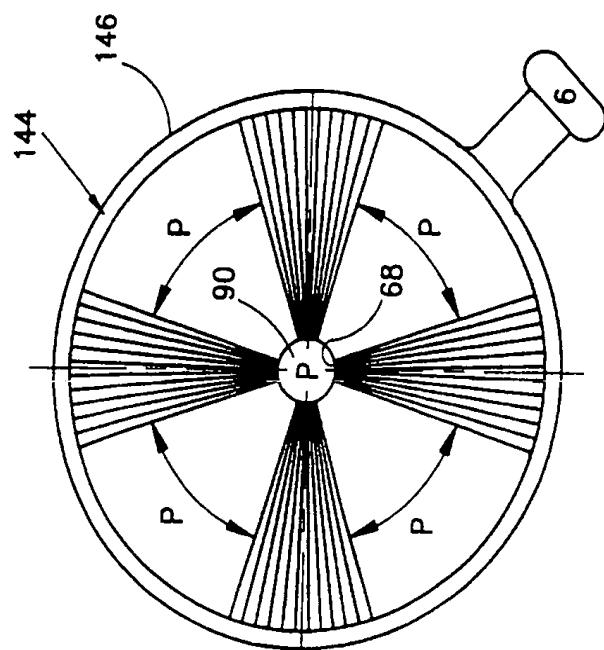


FIG. 35

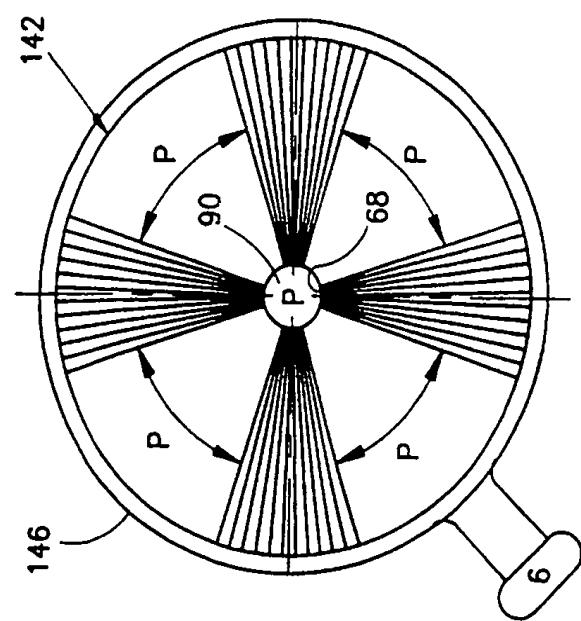


FIG. 34

15/19

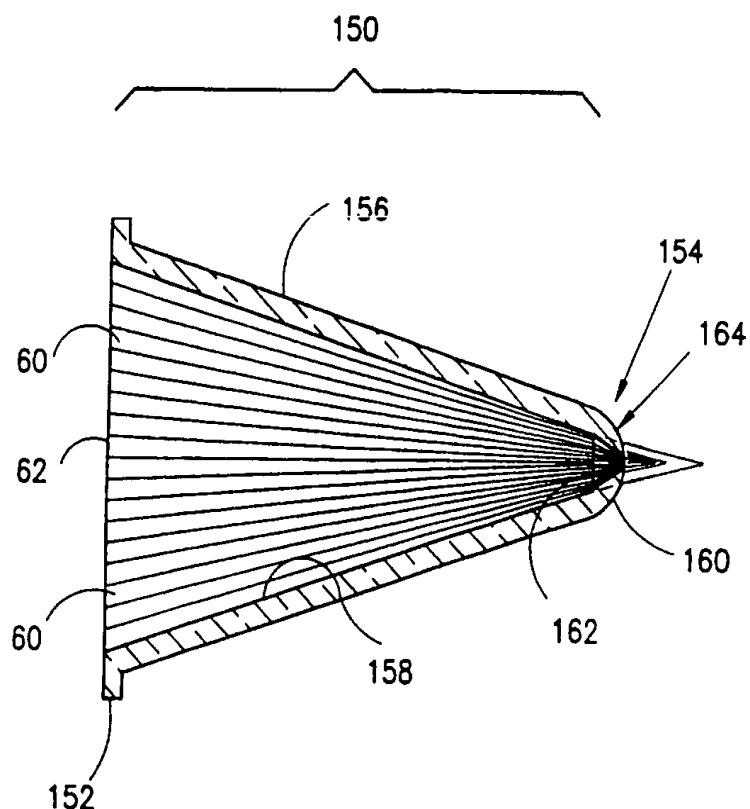


FIG. 36

16/19

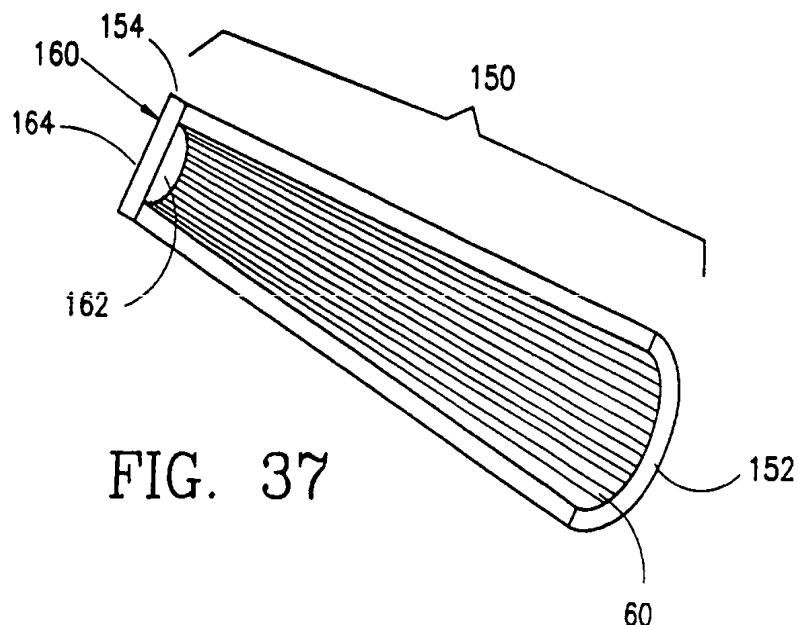


FIG. 37

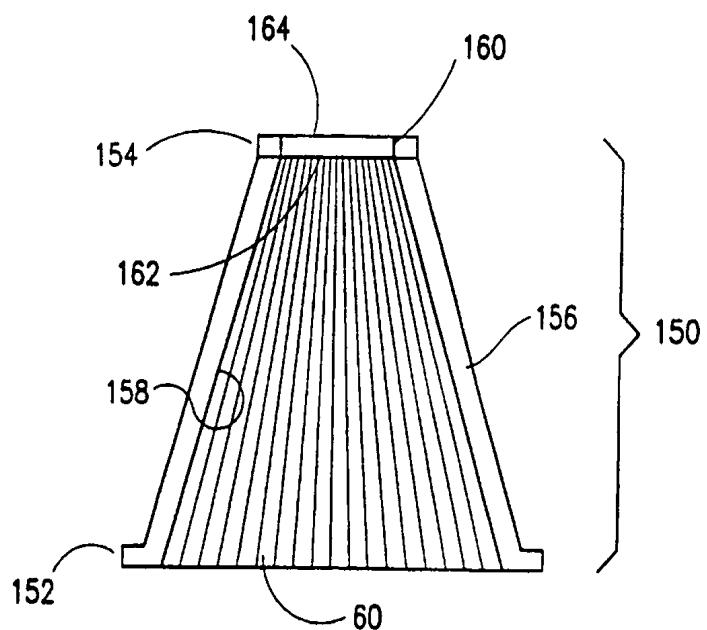


FIG. 38

17/19

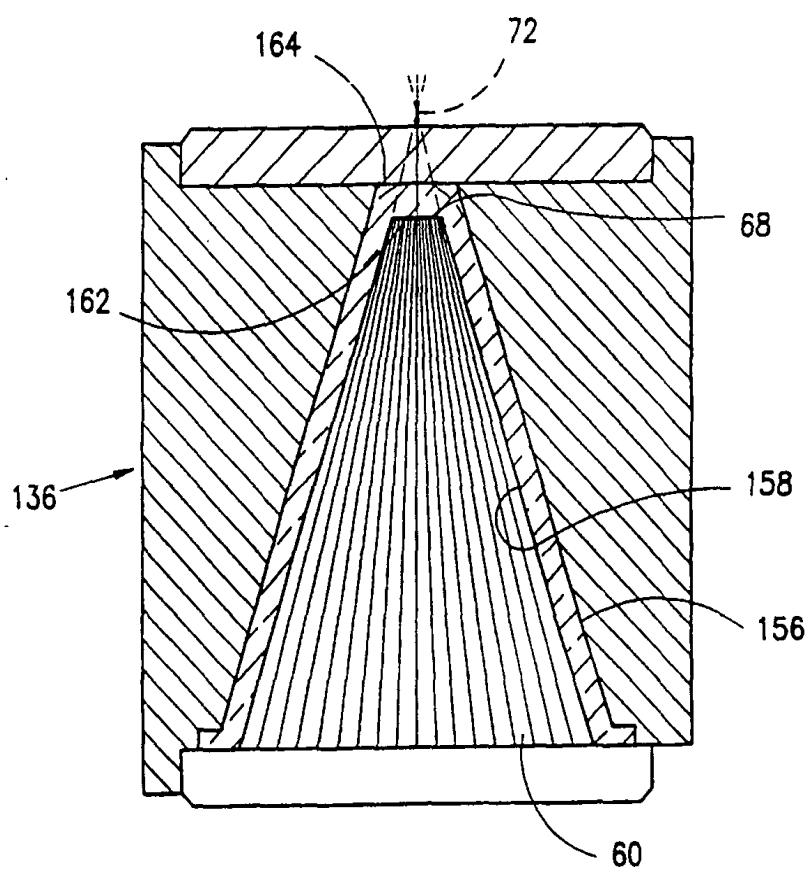


FIG. 39

18/19

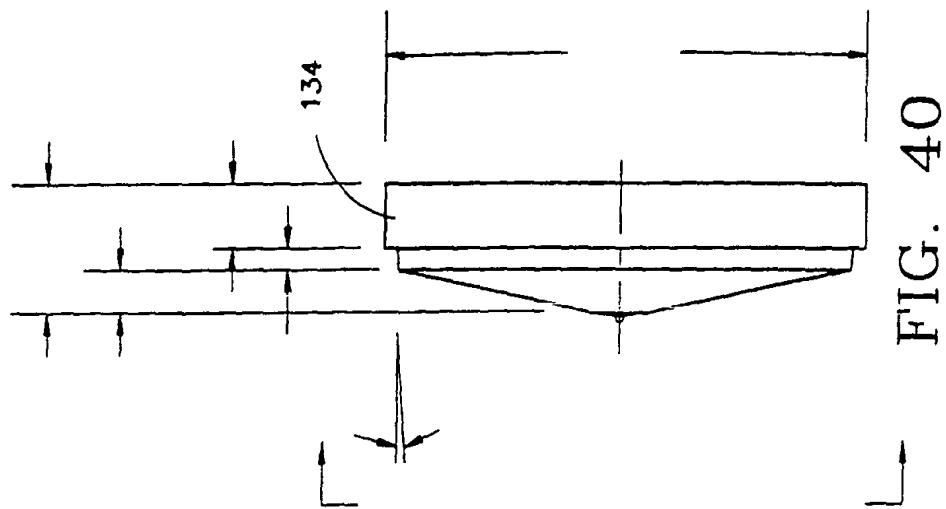


FIG. 40

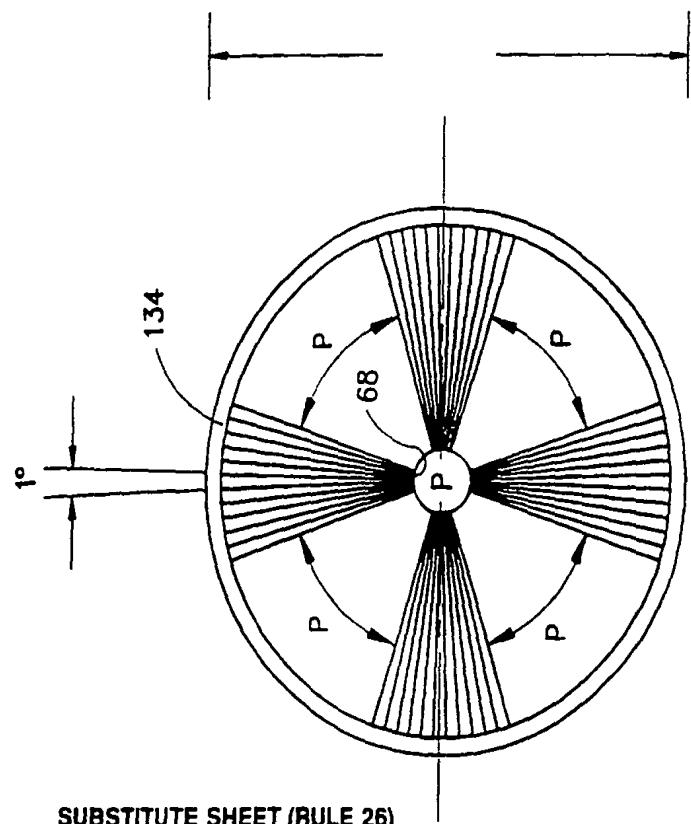


FIG. 41

SUBSTITUTE SHEET (RULE 26)

19/19

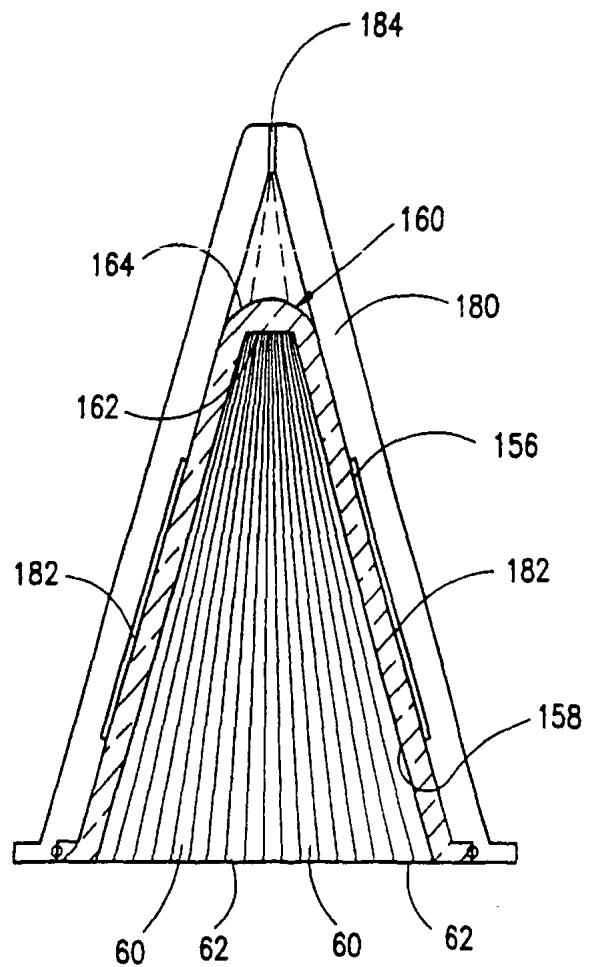


FIG. 42

INTERNATIONAL SEARCH REPORT

Int'l Application No
PCT/US 96/20726A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G02C7/02 G02B7/14

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G02B G02C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 772 113 A (PARKER WILLIAM S) 20 September 1988 cited in the application see column 6, line 12 - column 7, line 60; figure 4 ---	1,16
A	US 5 002 383 A (SISLER HAMPSON A) 26 March 1991 see column 2, line 28 - column 4, line 2; figures 1-8 ---	1,16
A	US 4 961 639 A (LAZARUS STUART M) 9 October 1990 see column 2, line 29 - column 6, line 15; figures 1-7 -----	1,16

 Further documents are listed in the continuation of box C. Patent family members are listed in annex.

* Special categories of cited documents :

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- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

- *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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- *&* document member of the same patent family

1 Date of the actual completion of the international search 21 May 1997	Date of mailing of the international search report 30.05.97
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentstaan 2 NL - 2280 HV Rijswijk Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl, Fax (+ 31-70) 340-3016	Authorized officer Sarneel, A

INTERNATIONAL SEARCH REPORT

Information on patent family members

Int'l Application No
PCT/US 96/20726

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